RAFFERTY-ALAMEDA PROJECT

ENVIRONMENTAL IMPACT STATEMENT

Souris Basin
Development
Authority

CHAPTER 8

WATER QUALITY

RAFFERTY/ALAMEDA ENVIRONMENTAL IMPACT STATEMENT

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WATER QUALITY

INTRODUCTION

The creation of reservoirs, by the very change in nature of the physical and hydrological regime, can affect water quality. Considering the construction of the Rafferty and Alameda Dams plus ancilliary developments, it is necessary to assess the potential impact such developments will have on water quality and if adverse effects are indicated, to propose appropriate mitigative measures. A detailed water quality review and assessment of the appropriate reaches of the Souris River System was carried out on behalf of the Souris Basin Development Authority. A copy of the consultant's report is included as Appendix 1.

SCOPE AND METHODOLOGY

The primary objective was to assess water quality related impact associated with the proposed Rafferty and Alameda dam and reservoir project, including a description and interpretation of existing water quality in the relevant areas, prediction and evaluation of potential water quality impacts associated with the proposed projects, and identification and evaluation of mitigative/remedial actions for any identified adverse impacts.

The geographical area under consideration was essentially limited to just below Nickle Lake to the international boundary for the main stem, the lower portion of Boundary Reservoir on Long Creek, and the lower reach of Moose Mountain Creek. Information for the assessment consisted of available water quality data from Saskatchewan and Canadian data banks, together with American information at the border crossing, and previous reports and studies respecting water quality or other activities affecting the project. No new field information was obtained nor was additional water quality surveillance undertaken.

The assessment considered the following components:

.1 Characterization of existing water quality.

- Acquisition of detailed and statistical data compilations for available sites on the Souris River and the major tributaries to assess variabilities, trends, and current use concerns.
- Identification and evaluation of various uses including wastewater effluent inputs to the system.

.2 Prediction and evaluation of water quality impacts.

- Selection of critical water quality parameters.
- Prediction and evaluation of potential water quality changes in the proposed reservoirs and downstream reaches using the available water balance model for the hydrological regimes and use of a water quality model for assessment of the key water quality parameters.
- Assessment, based on experience and relevant information, of other potential water quality effects.

.3 Mitigation

- Based on information from the predictive and evaluative exercises, identification and assessment of alternative mitigation and/or remedial actions which could be considered to address negative water quality impacts.

.4 An overall assessment

- Provision of a summary document indicating a net balance assessment of potential water quality impact on the proposed reservoir developments.

DATA BASES

Historical water quality data available on computer data bases from the provincial and federal Environment departments were retrieved. The State of North Dakota provided information on the station at Sherwood.

In addition to detailed retrievals, statistical summaries were requested for parameters considered to be of significance and where data permitted such analysis. The data from both federal and provincial data banks were combined for the major parameters except for Total Dissolved Salts (TDS).

The most comprehensive available report on water quality resulted from the Souris River basin study (Souris River Basin Study, 1978).

An inventory of users in the basin was obtained from Saskatchewan Water Corporation. Information and data respecting the major municipal sewage treatment facilities for Weyburn and Estevan, were obtained from the Water Quality Branch, Saskatchewan Environment and Public Safety.

EXISTING WATER QUALITY

The rivers' system under consideration is relatively long, and therefore in order to assess existing water quality data, it was considered appropriate to divide the system into three major reaches or sections:

- Souris River - Weyburn to Moose Mountain Creek confluence.
- Moose Mountain Creek - to the confluence of the Souris River.
- Souris River - Moose Mountain Creek confluence to the U.S. Border.

Within the first reach, there are three sub-reaches which relate to Long Creek. The existing water quality information, together with the uses and related impacts are generally discussed according to the described reaches.

Souris River Above Long Creek

This reach of the river above Long Creek serves many uses. Based on use information, and licensed user information obtained from the Saskatchewan Water Corporation, uses would include:

- Municipal water supply (City of Weyburn from Nickle Lake, and Town of Midale from Dead Lake).
- Recreation (Nickle Lake, Mainprize Park south of Midale, and miscellaneous uses within the water course).
- Irrigation (commercial and farm).
- Stock watering (range and feedlot).
- Fish and wildlife.
- Receiving waters for City of Weyburn treated sewage effluent.

It is apparent the existing water quality in this reach of the Souris River is quite variable, particularly on a seasonal basis. This seasonal variation not only reflects climatic differences but more important, is probably indicative of the change in the flow regime of the system. Generally, during the higher flow periods of spring and summer, the quality is superior to that observed during other times of the year. During winter the quality could deteriorate substantially, primarily due to ponding and ice cover concentration effects.

The system is quite high in the nutrients nitrogen and phosphorus, which, together with the present physical characteristics, tend to promote a favourable environment for the growth of aquatic vegetation and plankton. Low dissolved oxygen levels have been encountered during the summer and especially during the winter.

Long Creek

Although Long Creek headwaters west of Weyburn and it travels for a short distance through the United States, the interrelationship with the Souris River essentially focusses on Boundary Reservoir, which is located just upstream of the mouth of the creek and confluence with the Souris River. Boundary Dam and Reservoir was constructed in 1956 by the Saskatchewan Power Corporation primarily to provide a basin for cooling water to serve the adjacent thermal generating station.

Water quality and the aquatic environment in Long Creek is moderated by the presence of the instream reservoir and by the major purpose of the reservoir--use as a cooling pond for the 882 megawatt thermal generating station and as a receiving body for settled ash lagoon effluents.

The operation of the Boundary Dam Power Station requires large volumes of cooling water which results in a number of theoretical annual turnover cycles for the reservoir. Due to the configuration of the reservoir, most of the cooling water recycling occurs near the downstream end. This operation produces warm summer water temperatures and ice free conditions near the dam during the winter.

The critical operations of Boundary Reservoir are essentially governed by the needs of the generating station.

Reasonably comprehensive information exists on the water quality of the lower Long Creek, primarily due to work associated with the Souris River basin study and other studies related to Boundary Reservoir. At the lower end of the reservoir, the water quality is profoundly influenced by the operation of the Boundary Dam Power Station and the use of the reservoir as a source of cooling water and as a receptor for return water and other site effluents. This thermal reservoir maintains warm open water temperatures and in the wintertime is ice free at the lower end. This, together with the large circulation capability of the power station tends to keep the waters well mixed at the north end.

Based on water quality data, the general quality conditions are reasonably good within the reservoir. The major ions tend to vary with the season and probably reflect the ratio of inflow and evaporative loss. Nutrient levels are low relative to other prairie systems. Aquatic growth can flourish, but the magnitude and persistence of nuisance blooms of blue-green algae is remarkably absent and not experienced to the same degree as that in other eutrophic systems in the southern part of the province.

Other constituents such as heavy metals, biocides; etc., are present in trace amounts, but generally no use limitations would be prescribed based on available water quality guidelines.

With the current use of Boundary Reservoir as a direct source of water for Estevan, it is imperative that the quality be satisfactory to serve as a potable water source.

Souris River - Long Creek to Moose Mountain Creek

This 126 km reach of the river is characterized by increasingly better defined river channel and banks, and numerous but short length tributaries. The main tributary is Short Creek. In addition to agricultural practices associated with cultivated and native farmlands, coal mining activity is common in this part of the Souris River valley.

Major users would include irrigation (agricultural and commercial), industrial use, and fish and wild life. Primary impact on water quality would be derived from:

- City of Estevan treated sewage effluent.
- City of Estevan urban runoff.
- Estevan Generating Station activities.
- Direct and indirect drainage from coal mining operations.
- Agricultural runoff including cattle watering activities.

The majority of available water quality data is from the upper portion of this reach - No. 47 Highway and south of Bienfait (near Roche Percee). Water quality in this reach of the Souris River is variable particularly on a seasonal basis. This is the case for dissolved salts, dissolved oxygen and nutrients. While some of these variations may be explained by the sewage effluent and water runoff from the City of Estevan, they are more likely attributable to the change in the flow regime of the River. No significant trends were found on any of the measurements for heavy metals/trace substances or for biocides. Bacteriology counts within this reach were within reasonable tolerances with a higher incidence of coliform in the upper sections possibly due to the impact of the periodic Estevan sewage effluent discharges. The water has been subject to high turbidity and colour and is sufficiently fertile for the growth of aquatic vegetation.

Moose Mountain Creek

With headwaters immediately west of the town of Montmartre, Moose Mountain Creek is the major tributary, geographically, to the Souris River in Saskatchewan. The creek, and its rather short length tributaries, traverses agricultural lands and skirts Moose Mountain Provincial Park prior to entry into the Souris River. The creek has some significant reservoirs in its upper reaches including Moose Mountain Lake, and has a number of slough-like areas, particularly in the upper portion of the tributary. Licensed uses in the lower reach; i.e. from south of Carlyle to the mouth are rather limited to a private reservoir and an irrigator. Other uses would include domestic stock watering and wildlife and fish use. The creek could be the receptor of effluents from a number of communities but primarily on an indirect basis, i.e. through the short tributaries. Examples include Alameda, Arcola, Montmartre, Carlyle, Corning, and Kisby. Impacts are not expected to be significant. It is suspected that groundwater can also inflow into the creek under certain conditions, particularly in the lower reach.

Water quality data, limited to near the mouth, indicates considerable seasonal variability particularly for dissolved salts and dissolved oxygen. Open water measurements suggest sufficient phosphorus and nitrogen to support algae and other aquatic growths. For other substances concentrations have been relatively low.

Souris River - Moose Mountain Creek to the International Border

From the mouth of Moose Mountain Creek, this 64.7 km reach to the U.S. border is characterized by a well defined river channel and banks. The only urban centre adjacent to the river is the town of Oxbow. A shallow reservoir is created at Oxbow due to a small instream dam. The river traverses agricultural lands on which there is neighbouring petroleum activity.

Major uses include irrigation, recreation, and fish and wildlife. The Town of Oxbow uses a groundwater supply adjacent to the river for municipal purposes.

There are no point source discharges to this reach of the river. The Town of Oxbow's sewage lagoon, located to the southeast of the town and adjacent to the river, does not presently have a direct discharge. However, effluent loss through exfiltration towards the river is suspected.

It is presumed that stock also have use of the river valleys. The chief impacts would include normal agricultural runoff, including that from range cattle, together with any groundwater inflows.

Based on a reasonably good data base, this lower reach also exhibited water quality variations with the seasons and flow regime. Dissolved salts and nitrogen are higher in the winter while phosphorus and colour increase during spring and summer. Dissolved oxygen levels fluctuate daily and seasonally with low values periodically encountered. Generally heavy metal, trace substances, and biocides have been at very low or within acceptable concentrations.

Summary of Existing Water Quality in Souris River

Based on the current Saskatchewan surface water quality objectives (Saskatchewan Environment 1985), median water quality values would generally be in compliance over the spring and summer periods. Exceptions exist for nitrogen and phosphorus.

The newly issued Canadian Water Quality Guidelines (CCREM 1987) identify water quality guidelines according to various use categories. Available information suggests the values within the Souris River would tend to comply with the guideline numbers for the present uses.

WATER QUALITY PROJECTIONS

Approach

To forecast the water quality with the reservoirs in place and operating to provide projected uses and demands, both mathematical modelling techniques and subjective assessments were used. For modelling, the Water Quality Planning Model (a stream and reservoir model suitable for predicting steady state river conditions and seasonal or annual average reservoir quality) was used in connection with the flows indicated through the Water Balance Simulation Model. Parameters were selected that could be appropriately reviewed by the modelling approach. The model was calibrated using existing water quality data. Modelling criteria included foreseeable future municipal water demands, full contemplated irrigation development from Rafferty and Alameda Reservoirs, 50 percent apportionment, no groundwater inflow, Boundary Reservoir spill routing to Rafferty Reservoir, and projected future effluent qualities and quantities from Estevan and Weyburn. Two long-term simulations, based on historical hydrological data, were used for potential reservoir operating conditions. The periods examined included 1955 to 1974, which provides high runoff early in the time and from 1956 to 1974, which starts the reservoirs off in a low flow and slower filling cycle. These two cases could be representative of typical and poor situations respectively. In addition to dissolved salts, the modelling effort focussed on the nutrients - nitrogen and phosphorus - and potential impacts on dissolved oxygen within the reservoirs.

Other water quality characteristics were examined and predicted on the basis of available information, experience elsewhere, and probable operational situations.

Forecasts

Some differences were observed with water quality forecasts for each of the two hydrological scenarios. Following is a summary of the water quality effects from the construction and operation of Rafferty and Alameda Reservoirs both within the reservoirs and in the downstream reaches.

RAFFERTY AND ALAMEDA RESERVOIRS

Dissolved Salts

- Will vary with inflow availability.
- Average range suitable for municipal/domestic supply and for non-restricted irrigation.
- Within current Saskatchewan Municipal Drinking Water Objectives.
- For certain parameters, the reservoirs will provide improvements over present variations.

Nutrients

- Saskatchewan phosphorus objectives may be periodically exceeded, particularly in prolonged low inflow conditions and oxygen levels should generally be adequate for fish.
- Nutrient loading will provide eutrophic or productive conditions for aquatic plant growth.
- Nutrients will be beneficial for irrigation purposes.
- Nitrogen will continue to exceed Saskatchewan surface water objectives.

Dissolved Oxygen

- Oxygen levels should generally be adequate for fish.
- Potential problems in localized shallow bays and during long-term shallow depth conditions, especially under ice cover.

Physical Characteristics

- Localized high turbidity expected in upper portions during runoff.
- Apart from inflows, bank stability, water level fluctuations, and wind will be major factors for downstream conditions.
- Periodic incidents of high turbidity expected under high wind conditions, particularly for Rafferty.
- Colour improvements expected over present spring and winter levels.
- Water temperatures will be typical of Saskatchewan lakes and suitable for recreation.

Heavy Metals

- Generally expected to have low values within objectives/guidelines for identified uses.

Mercury

- May exhibit short-term increases of mercury accumulations in fish tissue
- Fish will require periodic monitoring to determine if problems develop.

Biocides

- Expected to be similar to other Saskatchewan water bodies.

Bacteriology

- General compliance for sensitive uses such as recreation and irrigation should be achievable during major demand periods.
- Possible high coliform counts in the vicinity of the Weyburn effluent discharge during the April and October discharge periods.

Aquatic Biology

- Expected to be quite productive, especially during initial years.
- Nuisance growths such as blue-green algae blooms could be anticipated in hot weather periods.
- Following reservoir stabilization, annual variations in growth densities may occur, typical of fertile south Saskatchewan lakes.
- Typical growths of emergent and submergent aquatic plants expected except in steep shoreline areas.

SOURIS RIVER DOWNSTREAM REACHES

Dissolved Salts

- Improvement expected for dissolved solids over existing quality during summer-fall periods. Winter conditions will be essentially unaltered.
- Projected levels should be satisfactory for unrestricted irrigation.

Nutrients

- Nitrogen may increase below Rafferty but should be reduced below Moose Mountain Creek with Alameda inflow.
- Any Estevan effluent will marginally increase concentrations during discharge periods
- Water quality will be good for irrigation, but some fish toxicity may arise.
- Due to potential phosphorus retentions in the reservoirs, concentrations may be somewhat less than presently observed during spring and summer.
- Sufficient phosphorus will likely be available to support aquatic vegetation growth.

Dissolved Oxygen

- Increased summer and fall flows should improve the dissolved oxygen regime.
- Winter conditions should be unaltered.

Physical Characteristics

- Turbidity reductions are generally anticipated particularly during spring season. Other seasons should have similar turbidity to present conditions.
- Open water colour levels could be reduced.
- No substantive change in temperatures over present experiences is forecast.

Heavy Metals

- As a result of upstream sedimentation, heavy metals are expected to be generally low - near or below detection limit.

Biocides

- Biocides are expected to be virtually non-existent except for typical low level detections.

Bacteriology

- Quality is generally expected to be suitable for all uses.

Aquatic Biology

- Sufficient nutrients should be available for algal growths, but increased flows should minimize ponding.
- Changes in the flow regime may provide a more favorable habitat for aquatic plant growth.

ASSESSMENT SUMMARY

Construction and operation of Rafferty and Alameda Reservoirs will create substantial changes to the regimes of the Souris River and Moose Mountain Creek. Primary water quality characteristics of interest with these projects include levels of dissolved salts, nutrient concentrations, dissolved oxygen, and resulting aquatic biological characteristics. The hydrological events that accompany the initial years of operation will have a significant influence on resulting water quality within the reservoirs. Rafferty Reservoir will be more affected. Generally, under the low inflow conditions, less satisfactory water quality will be realized. Although dissolved salts concentrations are expected to fluctuate, they are projected to be within a level satisfactory for most uses. The levels of the nutrients, phosphorus and nitrogen, are expected to be adequate in both reservoirs to provide a eutrophic status and promote aquatic biological productivity. It is expected that both reservoirs will be subject to typical aquatic vegetation growths such as algae and emergent and submergent aquatic plants that are experienced in southern Saskatchewan reservoirs and lakes. Rafferty Reservoir may be subject to more extensive and higher densities of algae than Alameda.* Dissolved oxygen depletion to undesired levels is possible, particularly in shallow areas under ice cover. Under prolonged low level conditions, fishkill problems could occur.

Downstream of the reservoirs, the augmented summer flows coupled with the inherent treatment and modifying effects of the reservoirs will tend to provide improved water quality during the summer and fall seasons. It is expected that winter conditions will be essentially unaltered.

Water quality is forecast to be generally suitable for all current intended uses. Periodic fluctuations in quality will occur, which will be largely dependent on the hydrological events. Some features associated with project developments will appropriately address potential water quality concerns. During design and construction, efforts will be made to enhance water quality protection where possible. In addition, ongoing water quality monitoring and assessment will be undertaken. This will provide not only an alert of any potential problems so that possible mitigation can be instituted, but also guidelines to ensure appropriate water quality management in terms of the overall water management programs for the system.

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* Some uses such as contact recreation and livestock consumption may be periodically inhibited depending on the types and persistence of algal production.

PROPOSED RAFFERTY AND
ALAMEDA RESERVOIRS

WATER QUALITY
IMPACT ASSESSMENT

Prepared for

SOURIS BASIN
DEVELOPMENT AUTHORITY

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LIST OF SYMBOLS AND ABBREVIATIONS

approx.	approximately
BOD	biochemical oxygen demand
CCREM	Canadian Council of Resource and Environment Ministers
cm	centimetre
cms	cubic metres per second
Cond.	electrical conductance
dam^3	cubic decametres
distr.	distribution
dnstrm.	downstream
DO	dissolved oxygen
f	fall
fed.	federal
fig.	figure
FSL	full supply level
G	greater than
gal.	gallon
gal/d	gallons per day
$g/m^2/d$	grams per square metre per day
gpm	gallons per minute
ha	hectare
Hwy	highway
JTU	Jackson candle turbidity units

kg	-	kilogram
kg/ha	-	kilograms per hectare
km	-	kilometre
L	-	less than
L/s	-	litres per second
m	-	metre(s)
m^2	-	square metres
m^3	-	cubic metres
max	-	maximum
MDW	-	municipal drinking water
MF	-	membrane filter
mg	-	milligrams
mg/L	-	milligrams per litre (10^{-3} grams per litre)
mg/m^3	-	milligrams per cubic metre
mg/m^2/month	-	milligrams per square metre per month
min	-	minimum
mL	-	millilitres
MPN	-	most probable number
m^3/s	-	cubic metres per second
MSL	-	minimum supply level
n	-	number
ng	-	nanograms
ng/L	-	nanograms per litre (10^{-9} grams per litre)
No.	-	number
NTU	-	nephelometric turbidity units

O_2 - oxygen

ortho - orthophosphorus

ppb - parts per billion

ppm - parts per million

prov. - provincial

r - correlation coefficient

ref. - reference

Res. - reservoir

SAR - sodium adsorption ratio

scen - scenario

sp - spring

sp. - species

SPC - Saskatchewan Power Corporation

STD - standard

st.dev. - standard deviation

su - summer

SWC - Saskatchewan Water Corporation

TCU - true colour units

TDS - total dissolved solids

TKN - total kjeldahl nitrogen

TON - threshold odour number

TP - total phosphorus

ug - micrograms

ug/g - micrograms per gram

ug/kg - micrograms per kilogram

ug/L - micrograms per litre (10^{-6} grams per litre)

U.S. - United States

uS/cm - microsiemens per centimetre

USGS - United States Geological Survey

usie/cm - microsiemens per centimetre

w - winter

WBSM - water balance simulation model

WQPM - water quality planning model

WTP - water treatment plant

- greater than or equal to

- less than or equal to

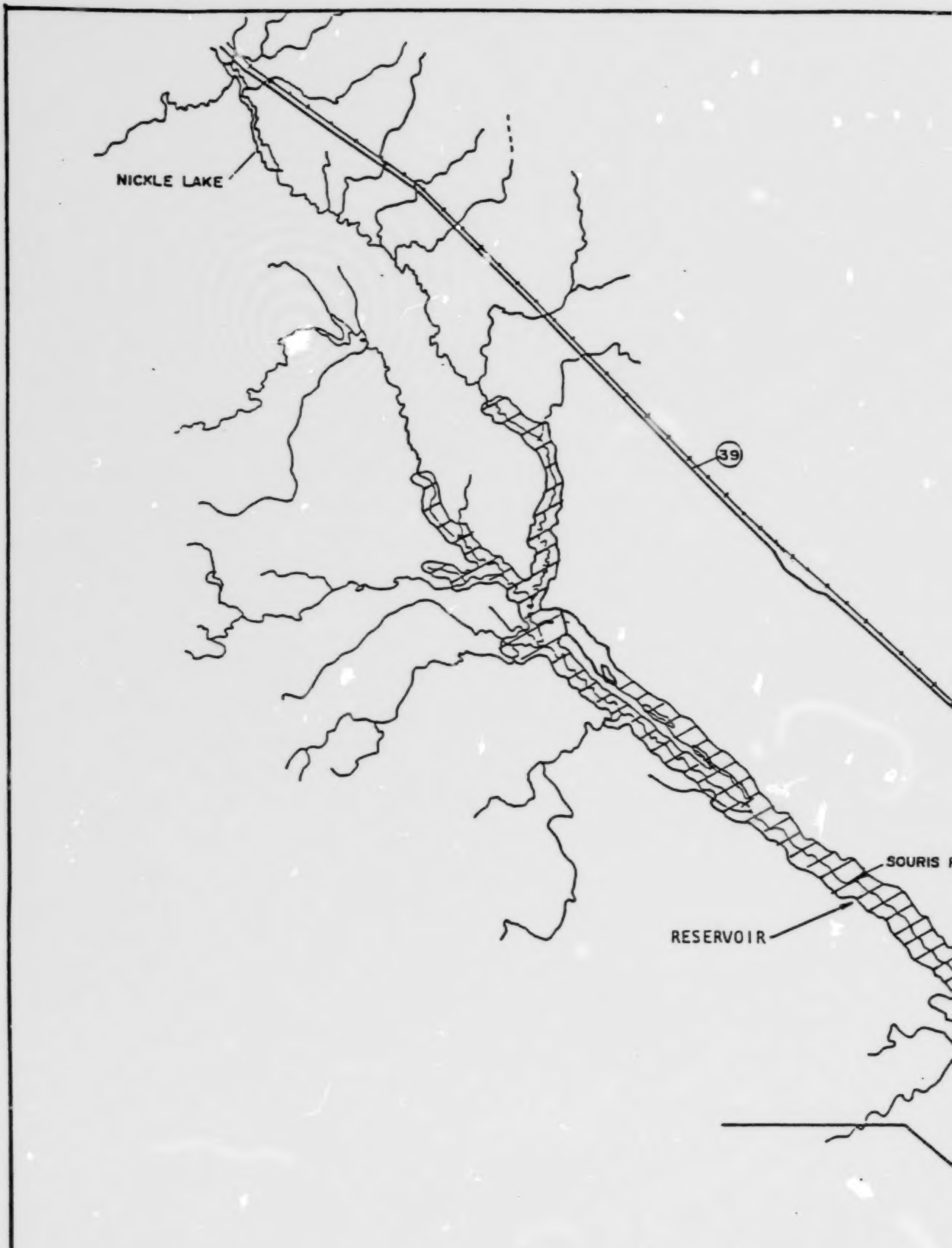
1. INTRODUCTION

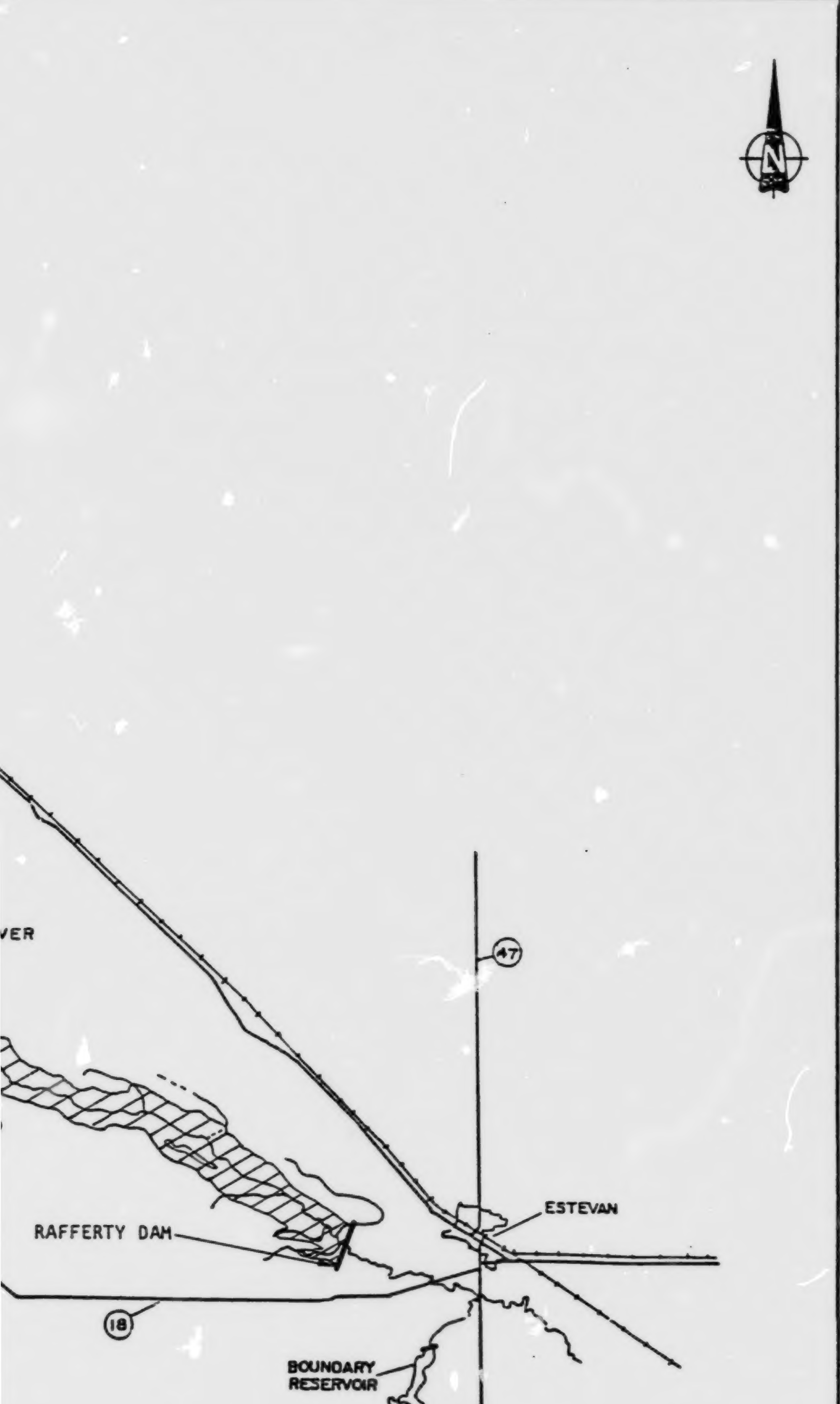
1.1 Background

The Souris River, which originates north of Weyburn, flows southeastward and crosses the international boundary into North Dakota before flowing north back into Canada in the neighbouring province of Manitoba. The main stem of the river plus the major Saskatchewan tributaries, Long Creek and Moose Mountain Creek, are typical prairie streams which characteristically depend on spring snowmelt or heavy precipitation events for the maintenance of any substantive flow. To provide more secure water supplies and/or flood control mechanisms, in-stream reservoirs are frequently considered and built. Presently, major examples include Nickle Lake southeast of Weyburn and Boundary Reservoir near the mouth of Long Creek.

The Souris Basin Development Authority is proposing the construction of dams and the creation of two major reservoirs--Rafferty Reservoir on the Souris River just upstream of Estevan, and Alameda Reservoir on Moose Mountain Creek upstream of its mouth. Locations are shown on Figures 2.1 and 2.2. These projects are described in more detail in other project documents.

Creation of reservoirs, by the very change in nature of the physical and hydrological regime, can affect water quality. Considering these alterations plus ancillary developments, it is desirable to investigate and assess potential impacts on water quality and if adverse effects are indicated, to examine potential mitigative measures.


NICKLE LAKE
39
SOURIS R
RESERVOIR

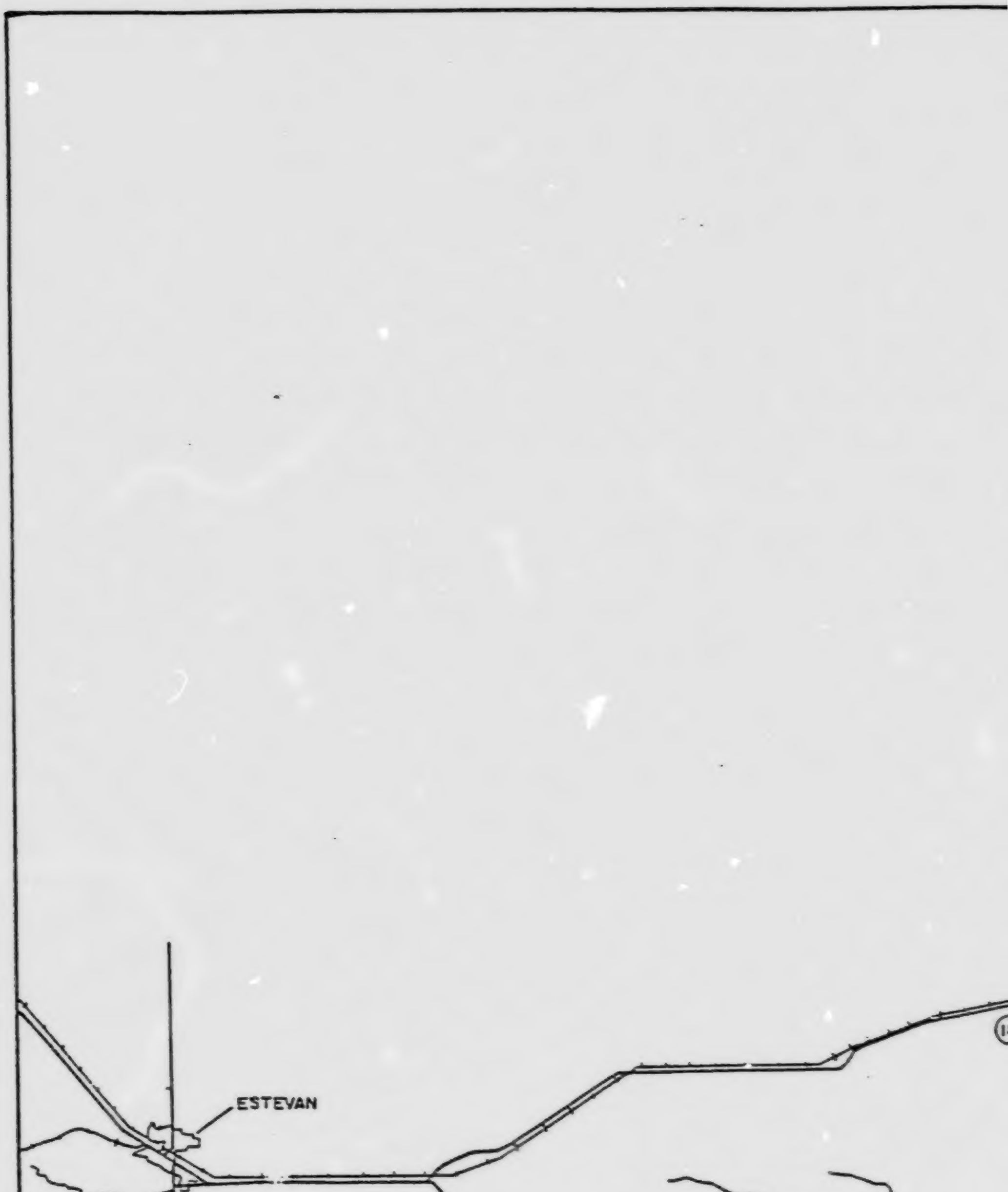

N
VER
47
ESTEVAN
RAFFERTY DAM
18
BOUNDARY RESERVOIR

SITE PLAN

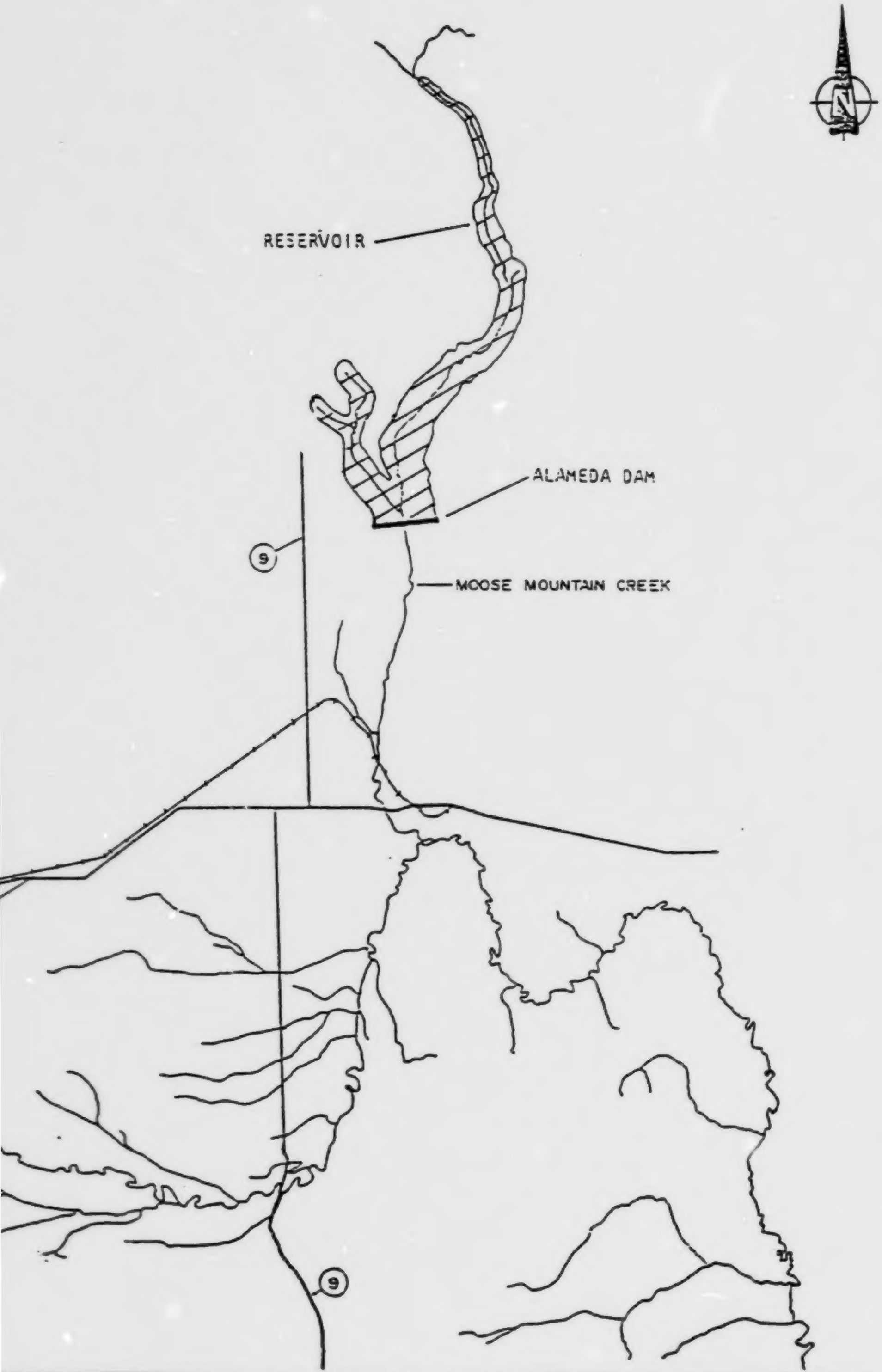
PROPOSED
RAFFERTY
RESERVOIR

SCALE 1:250 000 FIG. 2.1

M-R-2 — McDONALD & ASSOCIATES


ESTEVAN
SOURIS RIVER
49
39

3


RESERVOIR
ALAMEDA DAM
9
MOOSE MOUNTAIN CREEK
9
N

SITE PLAN

PROPOSED
ALAMEDA
RESERVOIR

SCALE 1:250 000 FIG. 2.2

M-R-2 — McDONALD & ASSOCIATES

1.2 Scope and Approach

The primary objective was to assess the water quality related impacts associated with the proposed Rafferty and Alameda dam and reservoir projects, including a description and interpretation of existing water quality in the relevant areas, prediction and evaluation of potential water quality impacts associated with the proposed projects, and identification and evaluation of mitigative/remedial actions for any identified adverse impacts.

The geographical area under consideration was essentially limited to just below Nickle Lake to the international boundary for the main stem, the lower portion of Boundary Reservoir on Long Creek, and the lower reach of Moose Mountain Creek. Information for the assessment consisted of available water quality data from Saskatchewan and Canadian data banks, together with American information at the border crossing, and previous reports and studies respecting water quality or other activities affecting the project. No new field information was obtained nor was additional water quality surveillance undertaken.

The assessment considered the following components:

.1 Characterization of existing water quality

- Acquisition of detailed and statistical data compilations for available sites on the Souris River and the major tributaries to assess variabilities, trends, and current use concerns.
- Identification and evaluation of various uses including wastewater effluent inputs to the system.

.2 Prediction and evaluation of water quality impacts

- Selection of critical water quality parameters.
- Prediction and evaluation of potential water quality changes in the proposed reservoirs and downstream reaches using the available water balance model for the hydrological regimes and use of a water quality model for assessment of the key water quality parameters.

- Assessment, based on experience and relevant information, of other potential water quality effects.

.3 Mitigation

- Based on information from the predictive and evaluative exercises, identification and assessment of alternative mitigation and/or remedial actions which could be considered to address negative water quality impacts.

.4 An overall assessment

- Provision of a summary indicating a net balance assessment of potential water quality impacts from the proposed reservoir developments.

The report is generally organized according to the above components. Details of the approach and methodology and findings are included in the following sections.

2. EXISTING SURFACE WATER QUALITY

2.1 Information/Data Bases

Historical water quality data available on computer data bases from the provincial and federal environment departments were retrieved. In addition, the State of North Dakota was requested to provide information on the station at Sherwood. Within the Saskatchewan portion of the Souris basin, 37 surface water quality sampling stations were identified. These included 10 considered to be duplicate sites, i.e. where both provincial and federal agencies had identical collection stations or where the agencies had adjacent stations which were in close enough proximity to be considered a single site. Where duplicate stations existed, data were combined for the purposes of this review. The net water quality stations available were 27. These stations are listed in Table 2.1 in a downstream order according to the reach. The table also includes the periods of record for the associated water quality data according to the collecting agency. Figure 2.3 illustrates the location of the sites within the basin. Sites are designated in an alpha-numeric fashion with the first letter representing the name of the water body and the last three digits applying to the station number given by the provincial and federal data management systems, Esquadat and Naquadat respectively.

In addition to detailed retrievals, statistical summaries were requested for parameters considered to be of significance and where data permitted such analyses. The data from both federal and provincial data banks were combined for the major parameters except for TDS. TDS had to be segregated since the methodology differs between the agencies. Seasonal and monthly water quality summaries for each station and the key water quality parameters were examined. Median and various percentiles were reviewed. Unfortunately, very little winter data were available. For the

TABLE 2.1
SOURIS RIVER BASIN
SASKATCHEWAN WATER QUALITY
STATIONS SUMMARY

Sampling Site No.	Location	Period of Record	Cumulative km from Border or Tributary Mouths	Comments
Souris River				
S114	1.5 km South of Lewvan	F - Apr/76 to Oct/76		- Near headwaters; upper reach station.
S001	3.2 km above Weyburn (off #13 and #39 Hwys @ grid road bridge)	F - Apr/75 to Oct/76 P - June/77 to Nov/82		- Upper reach station. - Combined prov/fed station.
S002	below Weyburn on #39 Hwy	P - Jan/77 to Nov/82		- Above Nickle Lake.
S003	below Nickle Lake Dam (above Weyburn sewage discharge	F - Apr/75 to Oct/76 P - Feb/70 to Nov/82		- Above sewage discharge from Weyburn. - Below Nickle Lake discharge. - Combined prov/fed station.
S022	Upstream of Weyburn lagoon discharge @ east boundary of S18-T7-R13-W3	P - Apr/84 to July/86		- New station implemented after new lagoon system operational.
S109	Southeast of Weyburn below effluent discharge @ grid road bridge.	F - Apr/75 to Oct/76	309.16	- Below sewage discharge from Weyburn.
S004	West of Halbrite	F - Aug/68 to June/75 P - Aug/70 to Oct/86	305.43 286.27	- Below Weyburn sewage discharge. - Above Jewel and Roughbark Creeks. - Combined prov/fed station.

TABLE 2.1 (Cont'd)

Sampling Site No.	Location	Period of Record	Cumulative km from Border or Tributary Mouths	Comments
	@ Roughbark Creek mouth		258.54	
S110	Below Roughbark Creek - 2.4 km southeast of Midale	F Apr/75 to Oct/76	257.56	- Below Roughbark Creek inflow.
S005	Above Long Creek @ #18 Hwy bridge near Estevan	F - Apr/75 to Oct/86 P - Oct/74 to Oct/86	191.13	- Combined prov/fed station. - Above Long Creek inflow. - Midale sewage discharge several miles above #18 Hwy.
	@ mouth of Long Creek		188.30	
S006	#47 Hwy @ Estevan	P - Dec/70 to Oct/86	187.85	- Below Long Creek inflow to Souris River. - Above Estevan sewage discharge.
S007	Approx. 1 mile below sewage inflow @ wooden bridge	P - Feb/74 to Oct/86	185.44	- Below Estevan sewage discharge.
S104	Near Estevan	F - May/60 to Apr/74	175.58	
S116	Approx. 2.4 km south of Shand @ grid road bridge	F - Apr/75 to Oct/76	171.22	
S008	South of Bienfait (old #39 Hwy @ Roche Percee)	F - Aug/68 to June/75 P - Aug/70 to Aug/86	158.49	- Below Short Creek inflow. - Combined prov/fed station.
S111	#39 Hwy 1.6 km east of Roche Percee	F - June/78 to Mar/79	153.34	

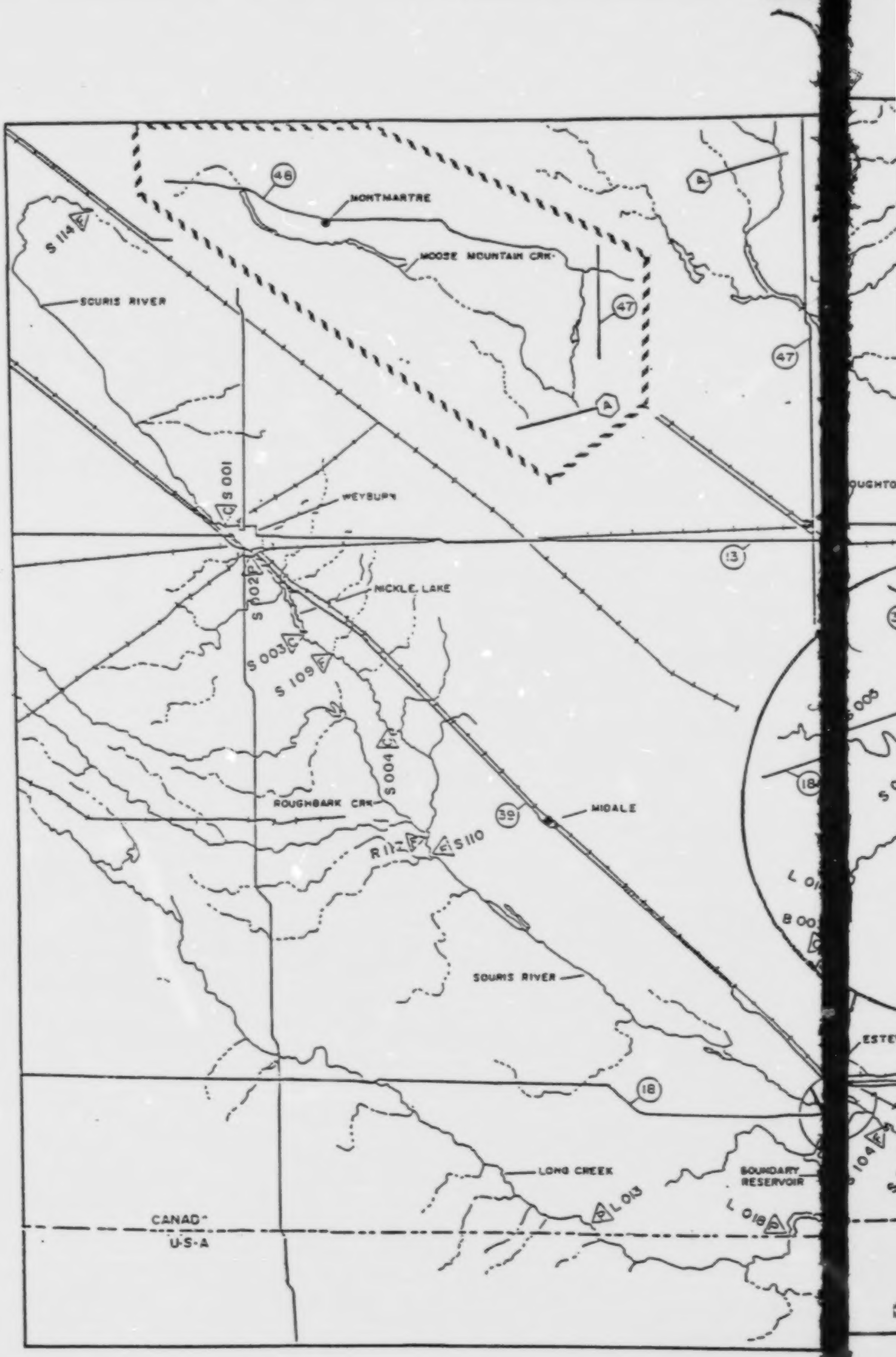
TABLE 2.1 (Cont'd)

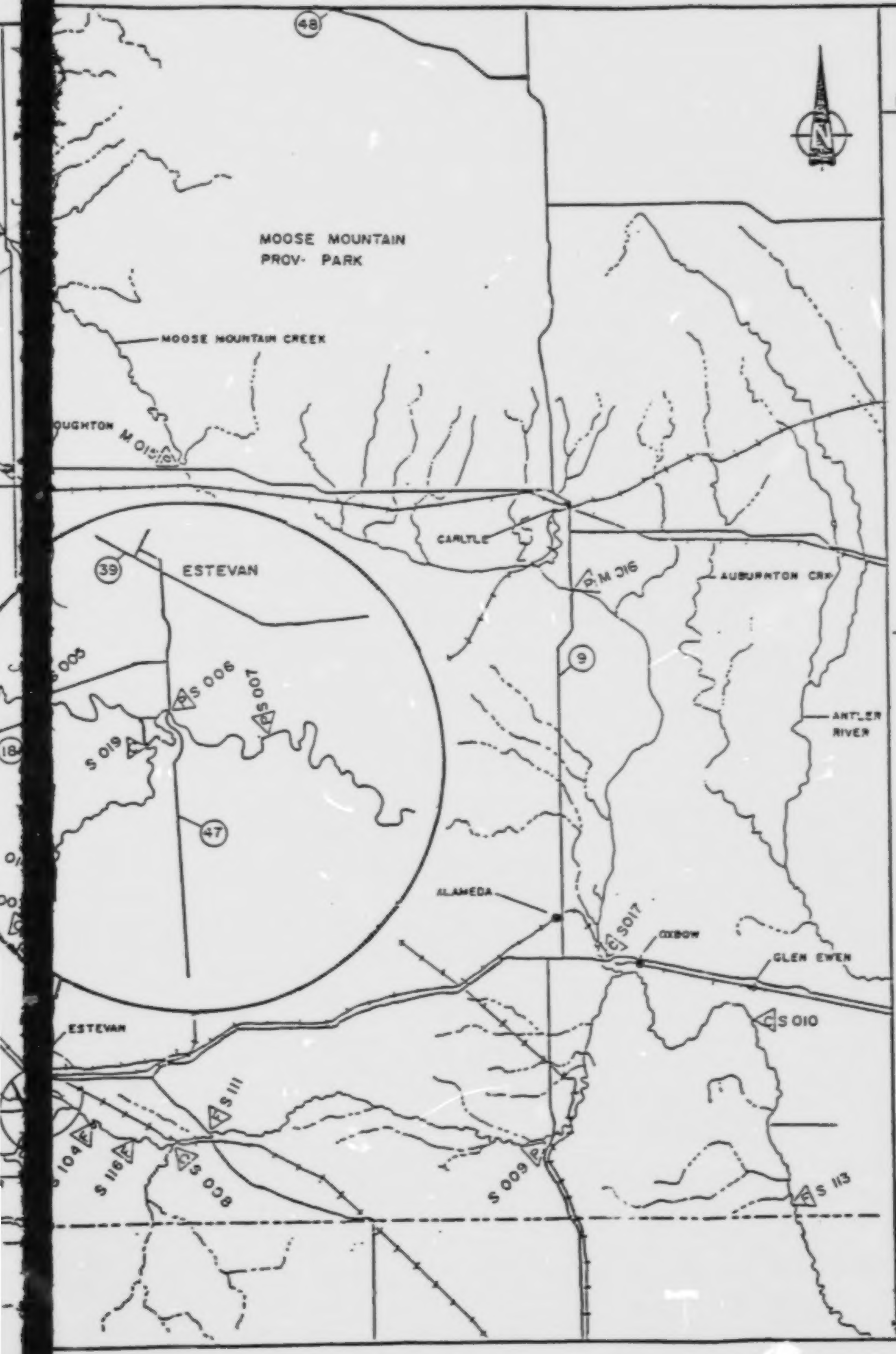
Sampling Site No.	Location	Period of Record	Cumulative km from Border or Tributary Mouths	Comments
S009	#9 Hwy south of Alameda	P - Sept/71 to Aug/81	92.74	- Above Moose Mountain Creek inflow.
	@ mouth of Moose Mountain Creek		64.65	
S010	Near Glen Ewen	F - Sept/60 to Dec/84 P - Aug/70 to Aug/81	28.99	- Above U.S. border. - Below Moose Mountain Creek inflow. - Combined prov/fed station.
S113	Near U.S. border	F - June/73 to Oct/73	0	- Immediately above U.S. border.
Roughbark Creek				
R117	@ mouth approx. 2.4 km west of Midale	F - Apr/75 to June/77	0	- Above Souris River.
Long Creek				
L013	Above Boundary Res. south of Outram	P - Oct/78 to Oct/81		- Creek station prior to entry to U.S. - Above Boundary Res.
L018	Immediately above Boundary Res.	P - Jan/82 to June/86	19.30	- Above Boundary Res.
B003	Boundary Reservoir - opposite intake for SPC generating station @ north end	F - Apr/75 to Feb/76 P - Feb/74 to Feb/84	4.79	- Cooling water intake. - Combined prov/fed station.

TABLE 2.1 (Cont'd)

Sampling Site			Cumulative km from Border or Tributary Mouths	
No.	Location	Period of Record		Comments
L014	Below Boundary Res. near Estevan	F - May/60 to May/75 P - Dec/70 to May/86	3.93	- Just below Boundary Res. - Just above inflow to Souris R. - Combined prov/fed station.
L019	@ mouth above Estevan WTP weir	F - Apr/75 to Jan/78 P - Apr/81 to Nov/86	0	- Estevan water supply. - Combined prov/fed station.
Moose Mountain Creek				
M015	East of Forget	P - June/77 to Aug/81	101.27	- First station upper end of creek. - Downstream of Montmartre sewage discharge.
M016	#9 Hwy south of Carlyle	P - June/77 to Aug/81	47.62	- Downstream of sewage discharges from Arcola and Carlyle.
M017	#18 Hwy west of Oxbow	F - June/72 to Apr/77 P - Mar/72 to Oct/86	2.14	- Downstream of Alameda sewage discharge. - Just above inflow to Souris River. - Combined prov/fed station.
	@ mouth		0	

F - Environment Canada
P - Saskatchewan Environment


46
MONTMARTRE
MOOSE MOUNTAIN CRK.
A
S 114 F
SOURIS RIVER
47
A
47
S 001 C
WEYBURN
OUGHTO
13
S 002 P
NICKLE LAKE
S 003 C
S 109 F
S 005
S 004 F
18
ROUGHBARK CRK.
39
MIDALE
R 112 F
F S 110
L 01
B 00
SOURIS RIVER
ESTE
18
LONG CREEK
BOUNDARY RESERVOIR
A L 013
L 018 P
S 104 F
CANADA
U.S.A.


48
MOOSE MOUNTAIN
PROV. PARK
MOOSE MOUNTAIN CREEK
M 015
CARLYLE
39
ESTEVAN
P M 016
AUBURNTON CRK.
9
S 005
P S 006
P S 007
S 019
ANTLER RIVER
18
47
ALAMEDA
C S017
OXBOW
GLEN EWEN
C S 010
ESTEVAN
S 111
S 104
S 116
C S 008
P S 009
F S 113

LEGEND

◁ - SAMPLING STATION
P - PROV. LOCATION
F - FEDERAL LOCATION
C - FED/PROV LOCATION
Sxxx - SOURIS STATION
Mxxx - MOOSE MOUNTAIN STAT.
Lxxx - LONG CREEK STATION
Rxxx - ROUGHBARK CRK. STAT.
—— - HIGHWAY
—+— - RAILROAD

NOTES

1. STATION NUMBERS REFER TO ESQUADAT IDENT. FEDERAL STATIONS REFER TO NAQUADAT IDENT.

WATER QUALITY STATIONS

SOURIS RIVER BASIN

SCALE 1:500 000 FIG. 2.3

M-R-2 — McDONALD & ASSOCIATES

purposes of this review, the seasonal periods were as those used in the Souris River Basin Study (1978):

- Spring - March 15 to June 15.
- Summer - June 16 to September 15
- Fall - September 16 to November 30
- Winter - December 1 to March 14

The most comprehensive available report on water quality resulted from the Souris River basin study. Much of the available water quality data was generated through the study over the period April 1975 to October 1976. Other primary water quality related studies were largely on Boundary Reservoir on Long Creek. In recent years the acquisition of water quality data appears to have diminished in frequency and sites sampled.

An inventory of users in the basin was obtained from Saskatchewan Water Corporation. Information and data respecting the major municipal sewage treatment facilities for Weyburn and Estevan, were obtained from the Water Pollution Control Branch, Saskatchewan Environment.[1]

The rivers' system under consideration is relatively long, and therefore in order to assess existing water quality data, it was considered appropriate to divide the system into three major reaches or sections:

- Souris River - Weyburn to Moose Mountain Creek confluence.
- Moose Mountain Creek - to the confluence of the Souris River.
- Souris River - Moose Mountain Creek confluence to the U.S. border.

Within the first reach, there are three sub-reaches which relate to Long Creek. The existing water quality information, together with the uses and related impacts, are generally discussed according to the described reaches.

---

[1] Now Water Quality Branch, Saskatchewan Environment and Public Safety

2.2 Souris River - Weyburn to Moose Mountain Creek Confluence

2.2.1 Souris River Above Long Creek

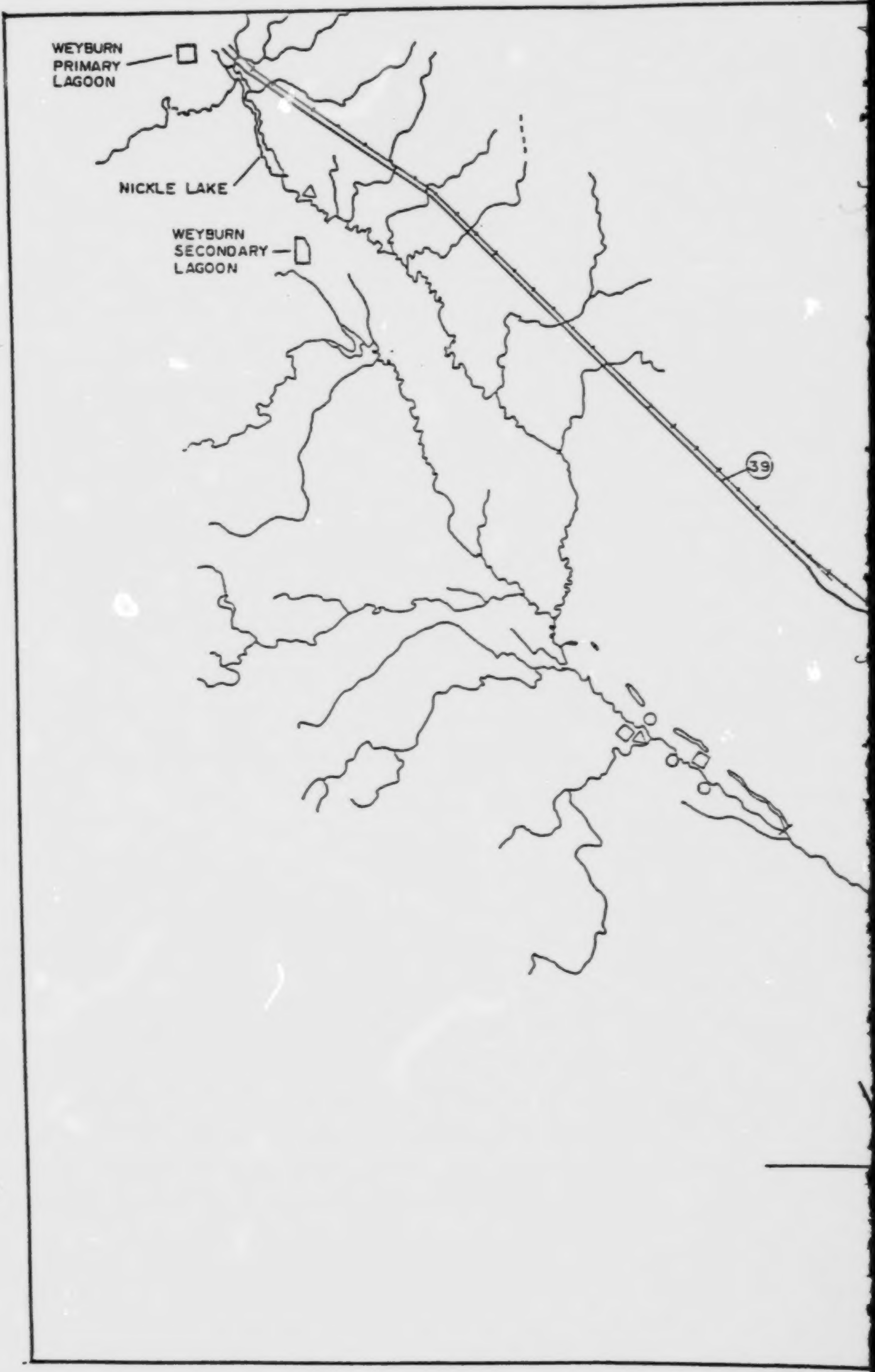
.1 General Factors/Uses

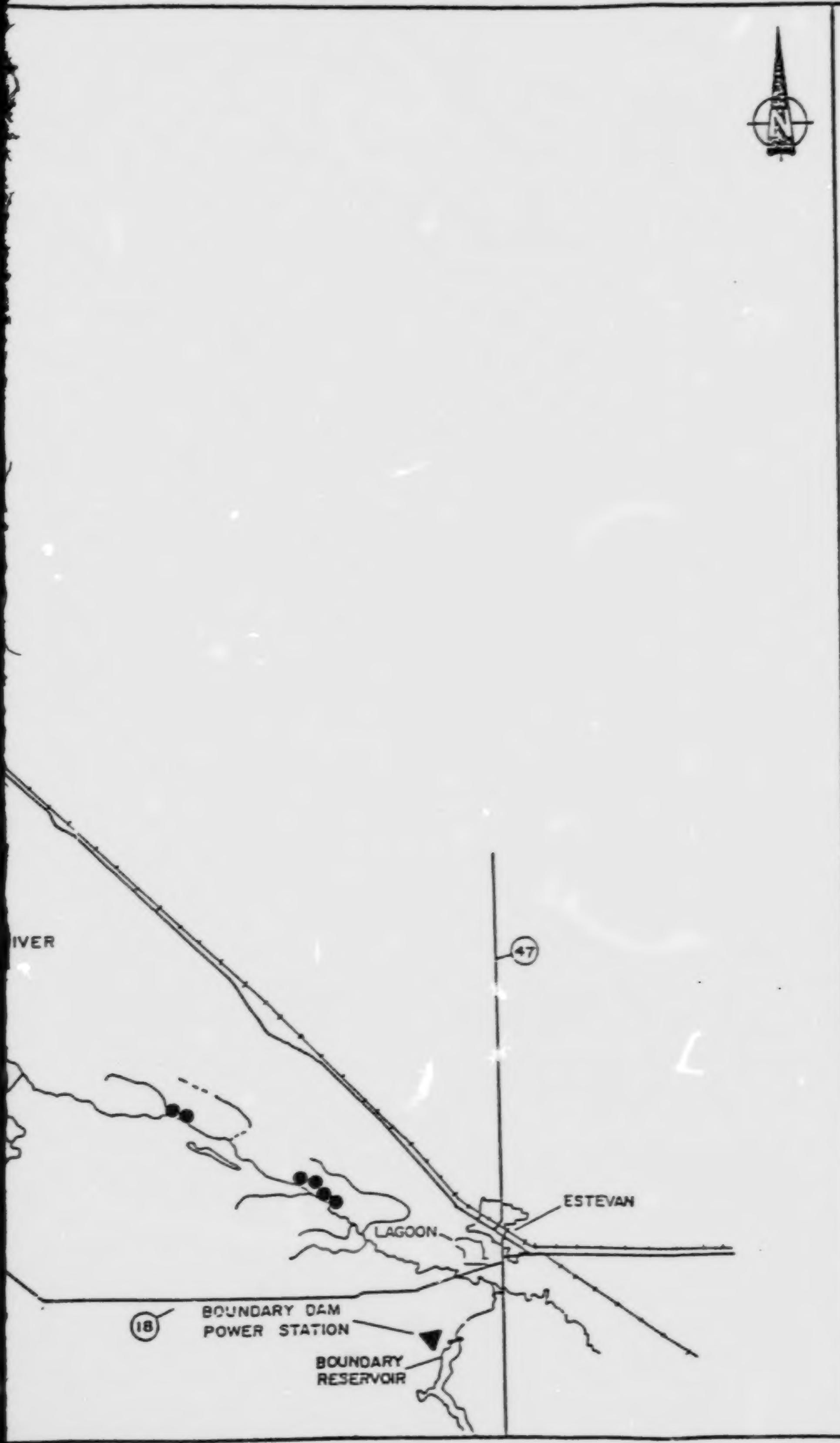
As noted on Figure 2.4, this reach of the river serves many uses. Based on use information and licensed user information obtained from the Saskatchewan Water Corporation, uses would include--

- Municipal water supply (City of Weyburn from Nickle Lake, and Town of Midale from Dead Lake).
- Recreation (Nickle Lake, Mainprize Park south of Midale, and miscellaneous uses within the watercourse.
- Irrigation (commercial and farm).
- Stock watering (range and feedlot).
- Fish and wildlife.

Major developments in this basin include Nickle Lake, which was expanded in 1982 to augment the water supply capabilities for the City of Weyburn, Dead Lake, numerous small reservoirs on tributaries, and the Yellowgrass marsh drainage project, which is above Weyburn and ultimately enters the headwaters of the Souris. The watercourse is typical of a prairie water stream and can often contain many potholes or low spots which create water pools during periods of minor or no flow.

Within this reach, there is only one major point of wastewater discharge. This is from the sewage treatment facilities serving Weyburn. In 1984 the sewage treatment facilities serving this city were considerably upgraded by the construction of remote


WEYBURN
PRIMARY
LAGOON
NICKLE LAKE
WEYBURN
SECONDARY
LAGOON
39


N
IVER
47
ESTEVAN
LAGOON
18
BOUNDARY DAM
POWER STATION
BOUNDARY
RESERVOIR

LEGEND

- ☐ Municipal use
- ■ Domestic use
- ○ Commercial irrigation
- ● Private irrigation
- ▲ Industrial area
- △ Recreation area

SOURIS RIVER
WATER USES

WEYBURN TO ESTEVAN

SCALE 1:250 000 FIG. 2.4

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secondary lagoon cells located to permit the discharge of effluent below the expanded Nickle Lake. The new facilities comprise 9 cells with a surface area of 105.2 ha (260 acres) and a storage capacity of 1,607,500 m³ (354 million gallons) (Per. Comm., Saskatchewan Environment 1987). Presently the facility is designed for a twice annual discharge. There is a potential that effluent could, in the future, be used for irrigation.

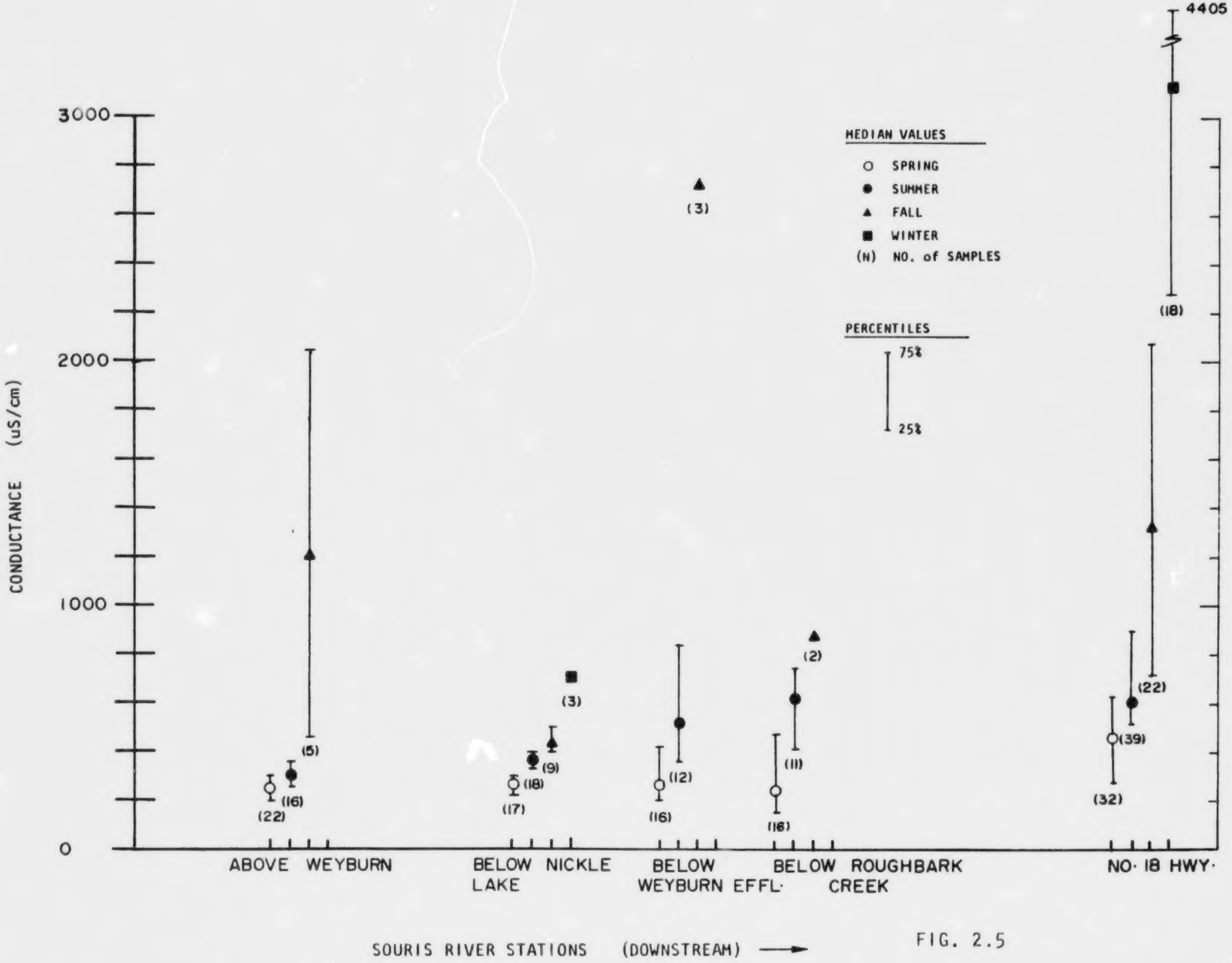
The primary water quality impacts to the system, relate to the runoff from urban and agricultural lands. To some extent, the runoff effect is tempered by the imposition of reservoirs on tributaries or on the main stem. The runoff or contributing quality is reflected by the characteristics of the land over which it originates. Typical inflows over fertile agricultural land would provide nutrients (nitrogen and phosphorus), dissolved salts from the soil leaching, and suspended material resulting from erosion or decay of vegetation.

.2 Water Quality Observations

General water quality observations, based on parameter groupings are discussed below. It should be noted that available data were collated for each station, and some stations will have more data over different time periods than others. Therefore strict comparisons between stations cannot be made.

a) Dissolved Salts

- Seasonal medians and 25th and 75th percentiles of conductance for major stations within this reach of the Souris River are shown on Figure 2.5.



CONDUCTANCE (uS/cm)
3000
2000
1000
0
4405
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
(22)
(16)
(5)
(17)
(18)
(9)
(3)
(16)
(12)
(3)
(16)
(11)
(2)
(32)
(39)
(22)
(18)
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) →

FIG. 2.5

. Generally, concentrations tend to increase downstream. As expected, the spring waters exhibit low levels of this dissolved salt indicator with median values below 500 uS/cm. During the summer, the values tend to increase, probably due to less flow, the effects of evaporation, and additional leaching during transit. Fall and winter values tend to demonstrate a potential for high concentrations. However these values are tempered by the relative quantity of data. However, increases would be anticipated due to concentration from either evaporation or ice cover, and the virtual absence of any flow. The waters below Nickle Lake tend to show less variability, which would be due to the modifying effect of the reservoir which would even out flow variations. During the summer period, median conductances in the main portion of the river (below Roughbark Creek to No. 18 highway just above Estevan) tended to be slightly in excess of 600 uS/cm.

. Based on federal data, the TDS (sum of ions) = 0.835 conductance - 22 (n=33; r=0.997)

. Of the specific major ions, more data are available for chloride which is normally considered to be conservative and unaffected by any stream purification or chemical processes. The seasonal median and 25th and 75th percentiles for chloride are plotted on Figure 2.6. Chloride values tend to reflect those observations made for conductance, i.e. low spring values with increasing concentrations during the subsequent seasons. Typically, summer chloride values would be considered to be less than 20 mg/L.

. Based on data where ionic species could be calculated, the waters in this reach of the Souris are basically a sodium sulphate water. There seemed to be little change between upstream and downstream compositions. Sodium trends are shown on Figure 2.7.

. Summer and spring values for sodium adsorption ratios typically ranged from 5 to 7. Percent sodium (percentage of available cations) ranged from 60 to 65.

b) Nutrients

. Seasonal median and 25th and 75th percentile values for total phosphorus are shown on Figure 2.8. Concentrations on a seasonal basis did not show any specific trends. Generally summer and spring concentrations are relatively comparable. The fall and winter data tend to be quite variable, i.e. above and below summer or spring concentrations, but this is possibly a reflection in the data volumes. It should be noted

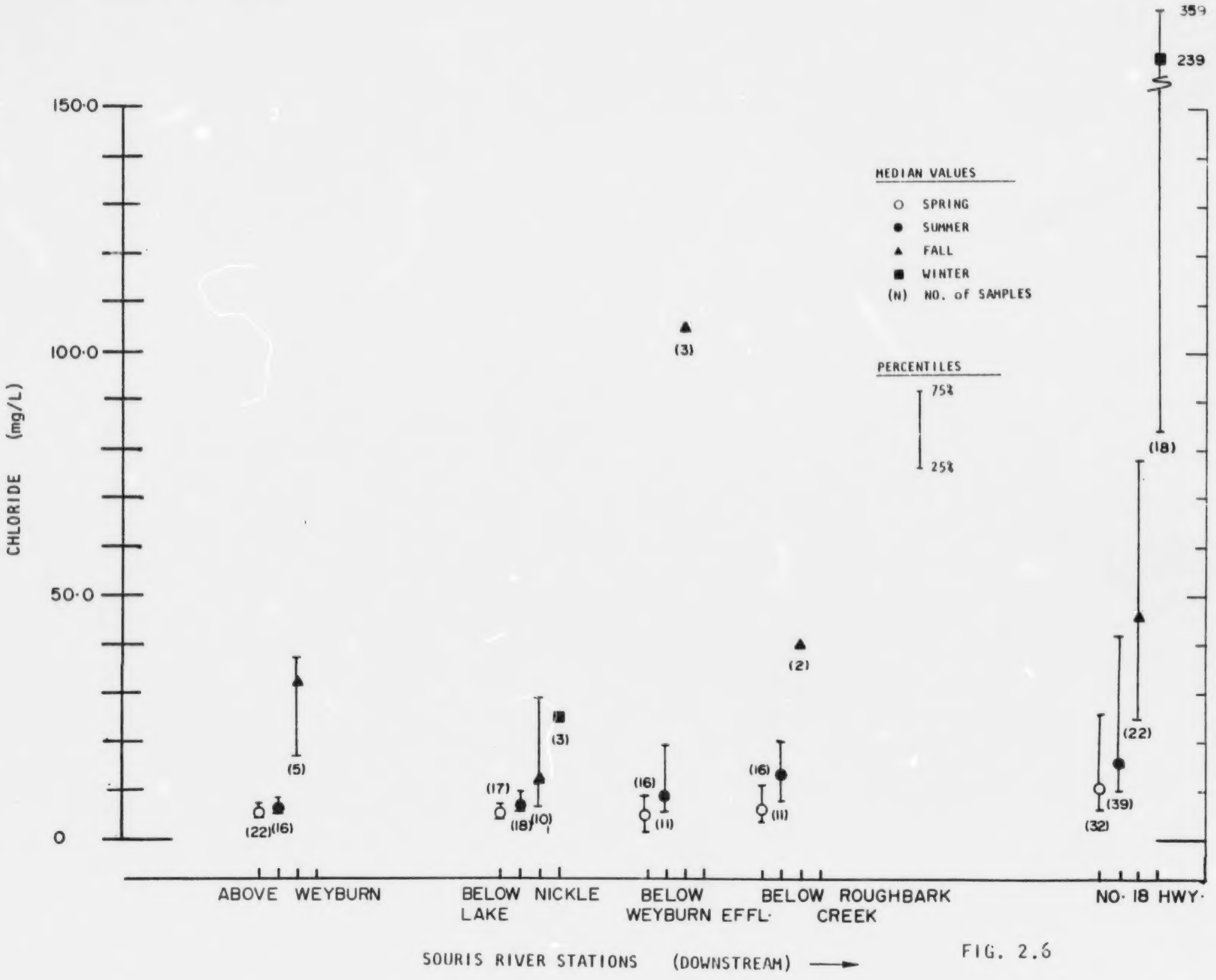

150·0
100·0
50·0
0
CHLORIDE (mg/L)
359
239
(18)
(22)
(39)
(32)
(3)
(2)
(16)
(11)
(16)
(11)
(17)
(18)
(10)
(3)
(5)
(22)
(16)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) ⟶

FIG. 2.6

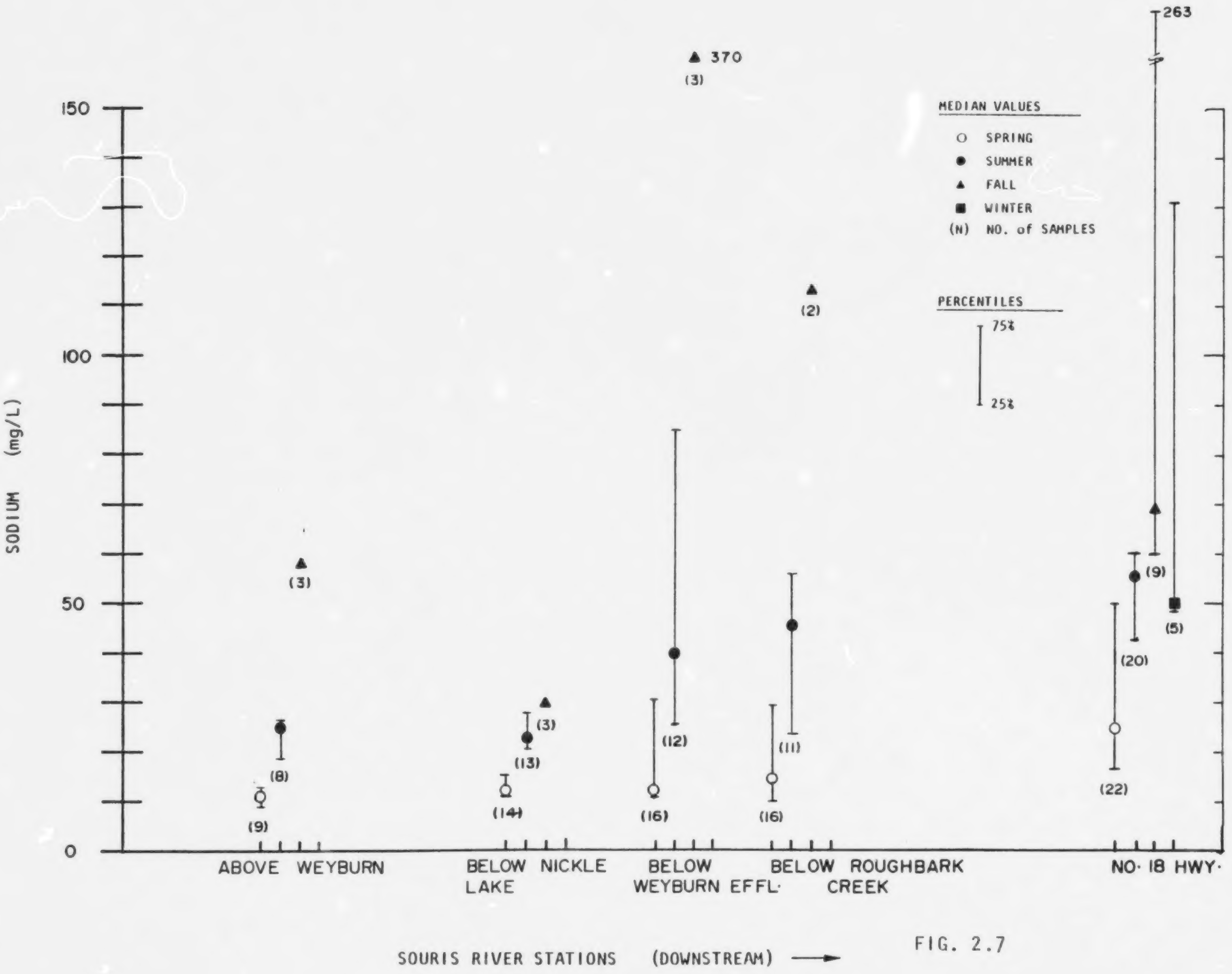

SODIUM (mg/L)
150
100
50
0
263
▲ 370
(3)
(9)
(8)
(3)
(14)
(13)
(3)
(16)
(12)
(16)
(11)
(2)
(22)
(20)
(9)
(5)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) ⟶

FIG. 2.7

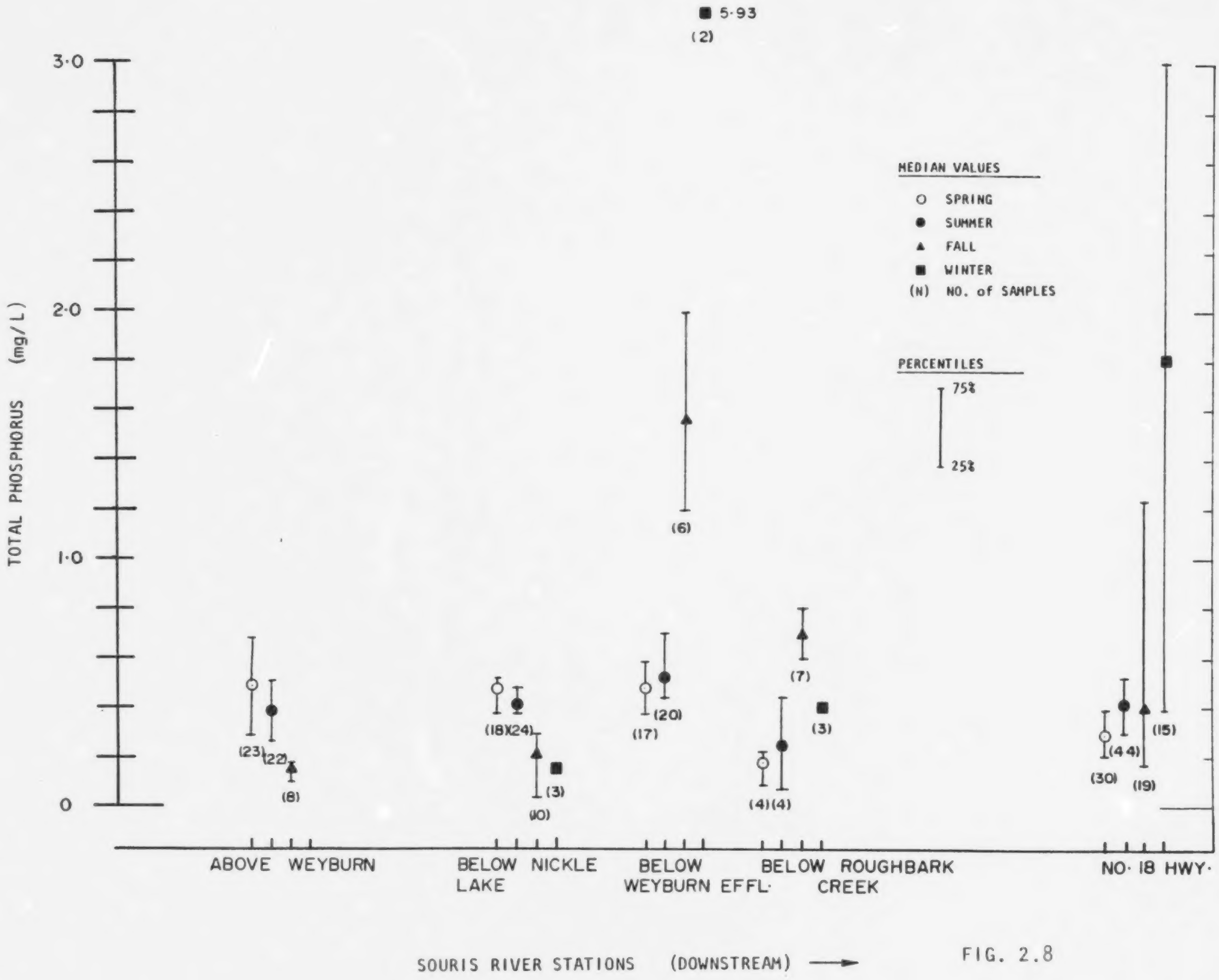

5·93
(2)
3·0
2·0
1·0
0
TOTAL PHOSPHORUS (mg/L)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
(23)
(22)
(8)
(18)(24)
(10)
(3)
(6)
(17)
(20)
(4)(4)
(7)
(3)
(30)
(44)
(19)
(15)
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) ⟶

FIG. 2.8

that the modification to the Weyburn sewage treatment facility (which previously had a virtual continuous discharge via a ditch to the river) has altered treatment performance and discharge periods, and the phosphorus concentrations could similarly be altered. The values at No. 18 highway are expected to reasonably typical of the river. Thus total phosphorus concentrations in the range of 0.3 to 0.4 mg/L would be anticipated.

. Total kjeldahl nitrogen trends on a seasonal basis for the reach are shown on Figure 2.9. Little data are available for winter. For the other seasons, the median concentrations for all stations except for below the Weyburn effluent discharge, are remarkably consistent. Based on stations immediately below Nickle Lake and at No. 18 highway, there is a possible decline of TKN levels within the reach. Presumably, this would be due to vegetation uptakes and particulate deposition. Typical values for total kjeldahl nitrogen in this part of the system could be expected to range from 1 to 2 mg/L.

. Limited ammonia nitrogen data, available for the No. 18 Highway station, indicated open water ranges of 0.02 to 0.75 mg/L (1985-1986). Calculated un-ionized ammonia concentrations yielded a maximum 0.047 mg/L and during July through October, 3 of 6 samples had values exceeding 0.02 mg/L.

c) Dissolved Oxygen

. As shown by Figure 2.10, median dissolved oxygen levels and the 25th and 75th percentiles reflect considerable variations seasonally. Summer values tend to be lower than those observed in the spring, perhaps due to warmer temperatures and the lower saturation level for dissolved oxygen. On the other hand, fall medians are typically higher than that observed during the summertime. Winter values (although sample population was low) were quite depressed and median values less than 5 mg/L were observed.

. Based on the observations, it would appear that the dissolved oxygen regime is affected by the temperatures, aquatic photosynthesis and respiration, and probable high sediment demands during periods of no aeration.

. During the spring through fall periods, the lower quartile of dissolved oxygen readings were all in excess of 6 mg/L. However a number of instances have been observed during

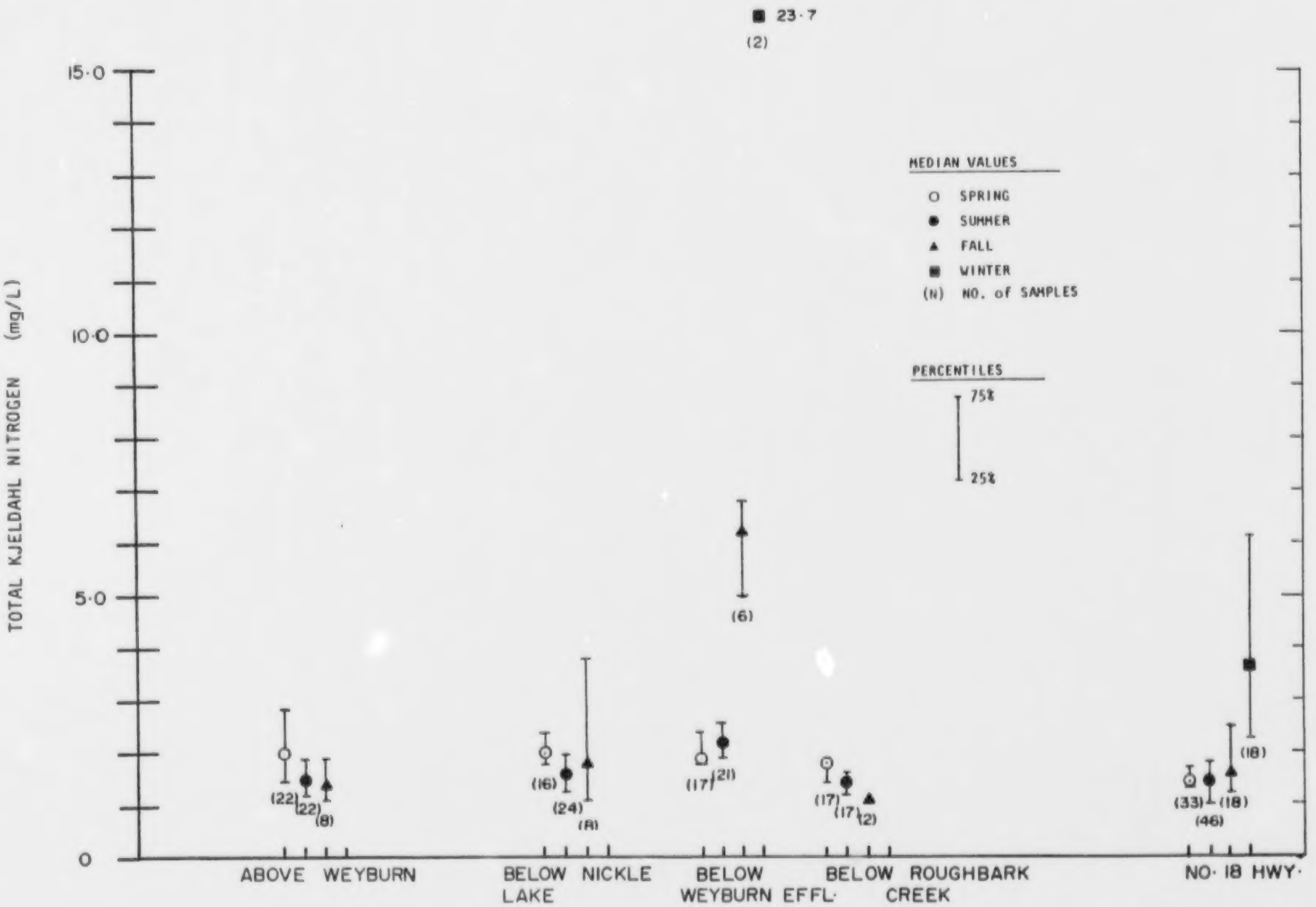

■ 23·7
(2)
15·0
10·0
5·0
0
TOTAL KJELDAHL NITROGEN (mg/L)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
(22)
(22)
(8)
(16)
(24)
(8)
(6)
(17)
(21)
(17)
(17)
(2)
(33)
(46)
(18)
(18)
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) ⟶

FIG. 2.9

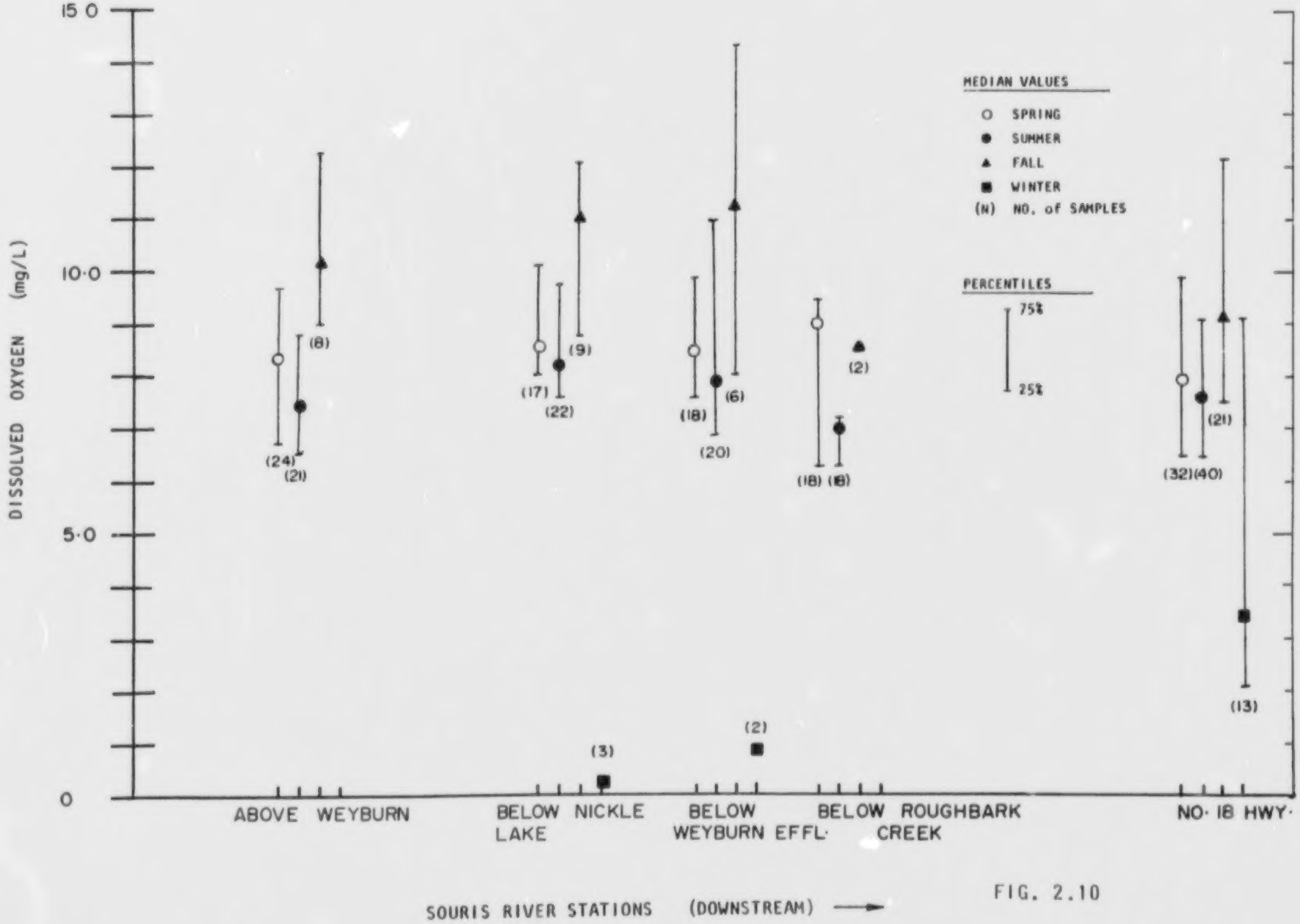

DISSOLVED OXYGEN (mg/L)
15 0
10·0
5·0
0
ABOVE WEYBURN
BELOW NICKLE LAKE
BELOW WEYBURN EFFL·
BELOW ROUGHBARK CREEK
NO· 18 HWY·
SOURIS RIVER STATIONS (DOWNSTREAM) ⟶
(24)
(21)
(8)
(17)
(22)
(9)
(3)
(18)
(20)
(6)
(2)
(18) (18)
(2)
(32)(40)
(21)
(13)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%

FIG. 2.10

summer and winter where the dissolved oxygen levels have fallen below 5 mg/L. At Highway No. 18, with the largest data base of 106 analyses, 3 summer and 11 winter values were less than this level.

d) Heavy Metals/Trace Substances

. The only station with a substantive data base for these constituents is No. 18 highway near Estevan. A summary of the data from 1978 through August 1986 and the parameters included is contained in Table 2.2. Some of the data show certain substantial variations. However in most cases, levels of heavy metals were relatively low. High total or extractable iron and manganese concentrations have been encountered. It is suspected much of this would be associated with particulate substances. Dissolved boron levels have exceeded 0.5 mg/L periodically. At No. 18 Highway, 13 out of 29 total samples and 7 out of 19 open water samples had values greater than 0.5 mg/L.

e) Biocides and Organochlorine Compounds

. The station at No. 18 highway provides virtually all of the available biocide and chlorinated organic compound data. A number of analyses are available for 2-4D, 2,4,5-T, alpha-BHC, and lindane. Periodic detections of 2-4D, lindane, and alpha-BHC have been recorded. All measurements for 2,4,5-T were less than detection limits. Biocide and organochlorine compound data for No. 18 highway are summarized in Table 2.3.

f) Bacteriology

. With the change in the Weyburn sewage effluent operations, the two primary stations available to assess present water quality are below Nickle Dam and the station at No. 18 highway. Median total coliform concentrations tended to be highest during the summer period. However, values were less than 1,000 organisms per 100 mL.

. Less fecal coliform data are available. Median values for Souris River tended to be highest at No. 18 highway and during the summer period. The high median value was 190 per 100 mL but values greater than 1000 were reported during the summer.

TABLE 2.2
HEAVY METALS/TRACE SUBSTANCES
EXISTING QUALITY SUMMARY
Souris River Above Long Creek (No. 18 Hwy Near Estevan)

		Data Base							
				Seasonal Distr.					
Parameter	Form	Period	Samples	Sp	Su	F	W	Range (mg/L unless noted)	Comments
Al	T	Jan 09/79 to Aug 12/86	26	6	4	8	8	0.025 - 7.5	
As	T	Jan 09/79 to Aug 12/86	36	6	12	8	10	0.0019 - 0.016	
	D	Apr 24/75 to Aug 30/76	5	1	2	1	1	0.0007 - 0.0052	
Ba	T	Nov 22/82 to Aug 12/86	14	3	2	5	4	0.031 - 0.22	
Be	T	Nov 22/82 to Aug 12/86	14	3	2	5	4	L0.001 - 0.001	13 @ L0.001
	E	Jul 28/75 to Aug 30/76	4	0	2	1	1	L0.01	
B	D	Jan 23/76 to Aug 12/86	29	6	7	6	10	0.01 - 3.6	Higher values tend to be in winter.
Cd	T	Oct 31/78 to Aug 12/86	27	5	6	9	7	L0.0005 - 0.04	3 @ L0.0005 3 @ L0.1 6 @ L0.02 12 @ L0.001
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.001 - 0.001	3 @ L0.001
Cr	T	Oct 31/78 to Aug 12/86	29	6	6	9	8	L0.001 - 0.028	4 @ L0.001 1 @ L0.002
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.015	
Co	T	Oct 31/78 to Aug 12/86	19	4	4	7	4	L0.001 - L0.10	1 @ L0.10 14 @ L0.001 1 @ L0.003
	E	Jul 28/75 to Aug 30/76	4	0	2	1	1	L0.002 - 0.003	2 @ L0.002
Cu	T	Oct 31/78 to Aug 12/86	28	5	6	9	8	0.002 - 0.033	1 @ L0.003
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.001 - 0.008	2 @ L0.001
CN^-		May 16/79 to Aug 12/86	21	5	4	5	7	0.00 - 0.044	
F	D	May 18/75 to Oct 13/76	40	18	15	5	2	0.05 - 1.0	
Fe	T	May 16/79 to Aug 12/86	24	6	6	5	7	L0.1 - 5.4	1 @ L0.1
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	0.13 - 7.3	
Pb	T	Oct 31/78 to Aug 12/86	28	5	6	9	8	L0.001 - 0.033	5 @ L0.002 1 @ L0.001
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.004 - 0.005	4 @ L0.004
Mn	T	Nov 22/82 to Aug 12/86	20	5	5	6	4	L0.01 - 3.0	2 @ L0.01
	D	Jul 28/75	1	0	1	0	0	L0.01	
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	0.03 - 6.6	

TABLE 2.2 (Cont'd)

		Data Base							
				Seasonal Distr.				Range	
Parameter	Form	Period	Samples	Sp	Su	F	W	(mg/L unless noted)	Comments
Hg	T	Oct 31/78 to Aug 12/86	26	4	5	9	8	L0.02 - 0.14 (ug/L)	6 @ L0.1 ug/L 6 @ L0.02 ug/L
	E	Jun 05/75 to Oct 21/75	3	1	1	1	0	L0.05 (ug/L)	
Mo	T	Jun 08/82 to Aug 12/86	16	5	2	5	4	L0.004 -0.040	7 @ L0.005 1 @ L0.004
Ni	T	Oct 31/78 to Aug 12/86	25	4	5	8	8	L0.001 - 0.060	3 @ L0.005 1 @ L0.05
Se	T	Jan 09/79 to Aug 12/86	17	4	2	5	6	L0.001 - 0.01	11 @ L0.001
	D	Apr 24/75 to Aug 30/76	5	1	2	1	1	L0.0005 - 0.001	3 @ L0.0005
Si	T	Nov 22/82 to Aug 12/86	9	2	2	2	3	L0.05 - 0.6	1 @ L0.05
Ag	T	Aug 07/79 Aug 12/86	17	4	3	5	5	L0.001 - L0.01	2 @ L0.01 9 @ L0.001
Tl	T	Nov 22/82 to Aug 12/86	14	3	2	5	4	L0.001 - 0.032	2 @ L0.001
U	T	Mar 01/83 to Dec 09/85	9	2	0	4	3	0.0011 - 0.014	
V	T	Jan 09/79 to Aug 12/86	17	4	2	5	6	L0.01 - 0.06	8 @ L0.01
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.001 - 0.004	1 @ L0.001
W	T	Nov 22/82 to Aug 12/86	13	3	2	5	3	L0.005 - 0;005	12 @ L0.005
Zn	T	Oct 31/78 to Aug 12/86	28	5	6	9	8	0.004 - 1.1	3 @ L0.1 2 @ L0.01
	E	Apr 24/75 to Aug 30/76	6	2	2	1	1	L0.001 - 0.004	3 @ L0.001

Notes:
1) L - less than
2) Sp - spring F - fall
Su - summer W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

TABLE 2.3

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Souris River Above Long Creek (No. 18 Hwy near Estevan)

	Data Base							
			Seasonal Distr.					
Parameter	Period	Samples	Sp	Su	F	W	Range (ug/L unless noted)	Comments
2,4-D	Oct 31/78 to Dec 09/85	19	1	7	7	4	L0.004 - 0.4	2 @ L0.5 7 @ L0.0004
2,4-DB	Jun 05/75 to Dec 09/85	16	1	5	6	4	L0.009	
2,4-DP	Jun 05/75 to Dec 09/85	16	1	5	6	4	L0.004	
2,4,5-T	Oct 31/78 to Dec 09/85	19	1	7	7	4	L0.002 - L2.5	1 @ L2.5 15 @ L0.002
MCPA	Jun 05/75 to Dec 09/85	20	2	6	7	5	L0.2	
MCPB	Jul 31/85	1	0	1	0	0	L0.05	
Silvex	Oct 01/79 to Dec 09/85	16	1	5	6	4	L0.004	
Herbicides, Total	Jul 31/85	1	0	1	0	0	L0.05	
Atrazine	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.1	
Barban	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.1	1 @ L0.4
Diallate	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.1	
Dicamba	Jul 31/85	1	0	1	0	0	L0.03	
Diclofop	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.05	
2,3,6-TBA	Jul 31/85	1	0	1	0	0	L0.03	
Tri-Allate	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.01	
Trifluralin	Jun 18/84 to Feb 25/86	4	0	2	0	2	L0.005	
Endaven	Jul 31/85 to Feb 25/86	3	0	1	0	2	L0.025	
Alpha-BHC	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001 - 0.01	8 @ 0.001
Gamma-BHC (Lindane)	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001 - 0.004	9 @ L0.001
Alpha-Chlordane	Nov 24/80 to Feb 25/86	14	0	5	5	4	L0.003	
Gamma-Chlordane	Nov 24/80 to Feb 25/86	14	0	5	5	4	L0.002	
Dieldrin	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.002	
Alpha-Endosulphan	Nov 24/80 to Feb 25/86	14	0	5	5	4	L0.001	
Beta-Endosulphan	Nov 24/80 to Feb 25/86	14	0	5	5	4	L0.003	
Endrin	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.002	
Heptachlor	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001	
Heptachlor Epoxide	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.002	
Hexachlorobenzene	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001	
O,P-DDT	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001	
P,P-DDT	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.004	
P,P-DDD	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.002	
P,P-DDE	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001	
P,P-Methoxychlor	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.01	

TABLE 2.3 (Cont'd)

	Data Base							
			Seasonal Distr.					
Parameter	Period	Samples	Sp	Su	F	W	Range (ug/L unless noted)	Comments
Mirex	Oct 01/79 to Feb 25/86	17	0	6	6	5	L0.001	
Aroclor 1242	Aug 05/81 to Nov 22/82	4	0	3	1	0	L0.002	
Aroclor 1248	Oct 01/79 to Jul 02/80	3	0	1	1	1	L0.002	
Aroclor 1254	Oct 01/79 to Nov 22/82	7	0	4	2	1	L0.002	
Aroclor 1260	Oct 01/79 to Nov 22/82	7	0	4	2	1	L0.005	
Aroclors, Total	Jan 22/80 to Feb 25/86	13	0	6	3	4	L0.002	

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

g) Miscellaneous

- Turbidity and colour measurements, although essentially limited to that collected during the Souris River Basin Study, indicated significant seasonal and site differences. Median spring turbidity values ranged from 150 to 190 JTU above and below Nickle Lake to 14.5 JTU downstream at No. 18 highway. Summer values had similar trends - 27.5 and 37.5 JTU for above and below Nickle Lake and 4.4 JTU at the downstream site. Colour values were high all seasons at below Nickle Lake - medians of 225, 85, and 50 relative units for spring through fall respectively. At No. 18 highway, the medians for the same seasons, were 75, 40, and 30 units.

h) Aquatic Vegetation

- The impoundments on the Souris River have been susceptible to growths of algae and aquatic weeds. Blue-green algal blooms consisting of such species of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* frequently occur on reservoirs such as Nickle Lake and Dead Lake. The reservoirs and ponded water within the river exhibit typical phytoplankton growths ranging from winter diatom predominance through green algae pulses and late summer blue-green algae blooms.
- Submergent and emergent vegetation also proliferate within the system. Macroscopic algae such as *Spirogyra* and *Cladophora* have been noted. Sedges and cattails exist along the edges and in sheltered backwater areas. In the reservoirs, pondweeds such as *Potamogeton Richardsonii* and *Potamogeton pectinatus* form extensive beds (Souris River Basin Study 1978). The conditions for various growth species seem to be conducive to a flourishing vegetation environment.

.3 Comments

From the available data and information, it is apparent the existing water quality in this reach of the Souris River is quite variable, particularly on a seasonal basis. This seasonal variation not only reflects climatic differences but more importantly probably is indicative of the change in the flow regime of the system. Generally, during the higher flow periods of spring and summer, the quality is superior to that observed during other times of the year. In the wintertime, the quality could deteriorate substantially primarily due to ponding and ice cover concentration effects. Major dissolved salts particularly reflect the seasonal inflow variations. During the spring, summer, and fall, levels are generally within acceptable levels for all uses. Although the presence of existing reservoirs such as Nickle Lake and small reservoirs on Roughbark Creek in the upper reach of the Souris River provide potential modifying influences, high turbidity and colour values have been recorded in the river below Nickle Dam. Interestingly, the limited data suggest significant decreases at the lower end of the reach.

The system is quite high in the nutrients nitrogen and phosphorus, which, together with the present physical characteristics, tend to promote an environment conducive to the growth of aquatic vegetation and plankton. Within reservoirs, periodic blooms of nuisance blue-green algae have been encountered.

The river has been subjected to depressed dissolved oxygen levels during summer and winter. More frequently the occurrences of levels below 5 mg/L happen under ice cover. Periodic measurements of ammonia nitrogen and calculated values of un-ionized ammonia indicate potential toxicity situations for fish. These incidents, coupled with the low oxygen concentrations, may presently restrict the availability of favourable fish habitat.

For irrigation purposes, available water quality information suggests the water would generally be suitable for the type of crops normally grown and for the soil characteristics, although periodic high sodium adsorption ratios and boron levels have been obtained. Based on values obtained at #18 Hwy, the concentrations of herbicides, pesticides, and other similar compounds have been minor and typical of other Saskatchewan surface waters.

The effects of the recently modified Weyburn sewage treatment facility and its operational practices have not been properly evaluated. It is expected that these improvements should result in reduced impact to the river over an extended duration. However, the periodic high-rate discharges could tend to increase the potential length of effluent effects over that previously encountered.

Table 2.4 provides a comparison of Saskatchewan Quality Objectives, newly issued Canadian Water Quality Guidelines, and the quality observations for the Souris River at @18 Highway (where most of the data are available). This table essentially includes only parameters where corresponding data and objectives or guidelines are available. Generally median water quality values would be in compliance over the spring and summer periods for the Saskatchewan Surface Water Quality Objectives. Exceptions exist for both nitrogen and phosphorus. Coliform counts would also periodically exceed recommended values. Generally biocides and significant heavy metal concentrations are not exceeded.

Based on the foregoing, this reach of the Souris River could be considered typical of a prairie stream subject to the influences of flow and seasons. Periodically uses may be restricted, but no major water quality problem is apparent for the flows and nature of the stream.

2.2.2 Long Creek (Boundary Reservoir)

.1 General Factors/Uses

Although Long Creek headwaters west of Weyburn and it travels for a short distance through the United States, the interrelationship with the Souris River essentially focusses on Boundary Reservoir, which is located just upstream of the mouth of the creek and the confluence with the Souris River. Boundary Dam and Reservoir was constructed in 1956 by the Saskatchewan Power Corporation primarily to provide a basin for cooling water to serve the adjacent thermal generating station. The reservoir flooded approximately 13 km of the former Long Creek valley, which resulted in an irregular shoreline and variable morphometry-

TABLE 2.4

WATER QUALITY OBJECTIVES AND GUIDELINES

SUMMARY COMPARISONS

SOURIS RIVER ABOVE LONG CREEK

	Water Quality Objectives/Guidelines			
	Saskatchewan[1]	CCREM - CWQG[2]	Observed Ranges[3]	
Parameter	(mg/L unless noted)	(mg/L unless noted)	(mg/L unless noted)	Comments
Calcium	--	1000 livestock L200 cooling water	22.5 - 72.1*	Values tend to be lowest in sp; highest in w.
	(Total Hardness - 800 MDW)	--	(Total Hardness as $CaCO_3$ - 190-870*)	@ west of Halbrite, 1/7 samples G800, @ #18 Hwy, 2/49 samples G800.
Magnesium	200 - MDW	--	7 - 131*	Values tend to be lowest in sp; highest in w.
Sodium	300 - MDW	Depends on crop and soil type for irrigation	11 - 370*	Values tend to be lowest in sp; highest in w. @ #18 Hwy, 5/60 samples G300.
-% of cations	30 - 75%	--	--	@ below Nickle Lake, range is 20-30%, @ west of Halbrite, value is 24%, @ #18 Hwy, range is 22 - 65%.
-SAR	--	Restriction for irrigation: L3 none 3 - 9 slight - moderate L9 severe	--	@ below Nickle Lake, SAR range is 0.5 - 0.9, @ west of Halbrite, SAR value is 0.9, @ #18 Hwy, SAR range is 0.68 - 9.0.
Chloride	250 - MDW	250 drinking water 100 - 700 irrigation L600 cooling water	4.3 - 274*	Values tend to be lowest in sp; highest in w. @ #18 Hwy, 10/101 samples G250; 1/101 samples G600.
Bicarbonate	--	L600 cooling water	--	@ #18 Hwy, 6/70 samples G600.
	(Total Alkalinity 500 as $CaCO_3$ - MDW)	--	79 - 829*	@ #18 Hwy, 20/108 samples G500. total alkalinity.
Sulphate	500 MDW	1000 livestock L680 cooling water	11 - 1130*	@ #18 Hwy, 5/48 samples G500, @ #18 Hwy, 3/48 samples G680, @ #18 Hwy, 1/48 samples G1000.
TDS (Sum of ions)	1500 MDW	500 drinking water 500 - 3500 irrigation 3000 livestock L1000 cooling water	734 - 1415* (166 - 2608 calculated from conductance)	Values tend to be lowest in sp; highest in w. @ #18 Hwy, 1/6 samples G1500, @ #18 Hwy, 4/6 samples G1000, @ #18 Hwy, 5/6 samples G500, @ below Nickle Lake, 2/2 samples G500, @ west of Halbrite, 4/7 samples G500, @ west of Halbrite, 4/7 samples G1000, @ west of Halbrite, 2/7 samples G1500.
TKN	1.0 (total inorganic and organic N)	$\left.\begin{array}{l}\text{10.0 nitrate}\\ \text{1.0 nitrite}\end{array}\right\}$ drinking w $\left.\begin{array}{l}\text{100 } NO_3 + NO_2\\ \text{10 nitrite}\end{array}\right\}$ livestock 0.06 nitrite - aquatic life	1.1 - 23.7*	@ #18 Hwy, 99/121 samples G1.0.
Ammonia, Total	--	Depends on temp. and pH	L0.03 - 4.4*	Un-ionized ammonia was calculated; max @ #18 Hwy - 0.047 mg/L.
Phosphorus, Total	0.05 as P	--	0.1 - 5.93*	@ #18 Hwy, 136/137 samples G0.05.
Oxygen, Dissolved	5.0 min at any time	5.0 - 6.0 warm water aquatic biota 6.5 - 9.5 cold water aquatic biota	0.2 - 12.3*	Very low values observed during winter, especially downstream of major discharges. @ 18 Hwy, 14/106 samples L5.0.

TABLE 2.4 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Aluminum	--	0.1 if pH ≥6.5 $[Ca^{2+}]$ ≥4.0 mg/L & DOC ≥2.0 mg/L aquatic life 5.0 - 20.0 irrigation (depends on soil) 5.0 livestock	0.025 - 7.5	@ #18 Hwy, 24/26 samples G0.1 @ #18 Hwy, 1/26 samples G5.0
Arsenic	0.01	0.05 drinking water and aquatic life 0.1 - 2.0 irrigation (depends on soil) 0.5 livestock (5.0 when not added to feed)	0.0019 - 0.016	@ #18 Hwy 7/41, samples G0.01
Barium	1.0	1.0 drinking water	0.031 - 0.22	--
Beryllium	--	0.1 - 0.5 irrigation (depends on soil) 0.1 livestock	L0.001 - L0.01	--
Boron	0.5	5.0 drinking water 0.5 - 6.0 irrigation (depends on crop) 5.0 livestock	0.01 - 3.6	@ #18 Hwy, 13/29 samples G0.5
Cadmium	0.01 0.005 MDW	0.005 drinking water 0.2 - 1.8 aquatic life (depends on hardness) 0.01 irrigation 0.02 livestock	L0.0005 - L0.1	@ #18 Hwy, 2/33 samples G0.005 @ #18 Hwy, 1/33 samples G0.01 @ #18 Hwy, 1/33 samples G0.02
Chromium	0.05	0.05 drinking water 0.02 fish; 2.0 aquatic life; 0.1 irrigation 1.0 livestock	L0.001 - 0.028	@ #18 Hwy, 1/35 samples G0.02
Cobalt	--	0.05 - 5.0 irrigation (depends on soil) 1.0 livestock	L0.001 - L0.10	--
Copper	0.02	1.0 drinking water 2 - 4 aquatic life (depends on hardness) 0.2 - 1.0 irrigation (depends on crop) 0.5 - 5.0 livestock (depends on animal)	L0.001 - 0.033	@ #18 Hwy, 6/34 samples G0.02.
Cyanide	0.01	0.2 drinking water 5.0 (free cyanide as CN) aquatic life	0.00 - 0.044	@ #18 Hwy, 3/21 samples G0.01
Fluoride	1.5 1.5 MDW	1.5 drinking water 1.0 - 15.0 irrigation (depends on soil) 2.0 livestock (1.0 if feed contains fluoride)	0.05 - 0.21	--
Iron	0.3 0.3 MDW	0.3 drinking water 0.3 aquatic life 5.0 - 20.0 irrigation (depends on soil)	L0.1 - 7.3	@ #18 Hwy, 21/30 samples G0.3
Lead	0.05	0.05 drinking water 1 - 7 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.033	--
Manganese	0.05	0.05 drinking water 0.2 - 10.0 irrigation (depends on soil)	L0.01 - 6.6	@ #18 Hwy 20/31 samples G0.05

TABLE 2.4 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Mercury	0.1 ug/L 1 ug/L MDW	1 ug/L drinking water 0.1 ug/L aquatic life 3 ug/L livestock	L0.02 - 0.14 ug/L	@ #18 Hwy, 1/29 samples G0.1 ug/L.
Molybdenum	--	0.01 - 0.05 irrigation (depends on soil) 0.5 livestock	L0.004 - 0.040	--
Nickel	--	25 - 150 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.060	--
Selenium	0.01	0.01 drinking water 0.001 aquatic life 0.02 irrigation 0.05 livestock	L0.0005 - 0.01	@ #18 Hwy, 4/23 samples G0.001
Silica	--	L50 cooling water	L0.05 - 0.6	--
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.001 - L0.01	@ #18 Hwy, 6/17 samples G0.0001
Uranium	0.02 MDW	0.02 drinking water 0.01 - 0.1 irrigation (depends on soil) 0.2 livestock	0.0011 - 0.014	--
Vanadium	--	0.1 - 1.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.06	--
Zinc	0.05	5.0 drinking water 0.03 aquatic life 1.0 irrigation, if soil pH L6.5; 5.0, if soil pH G6.5	L0.001 - 1.1	@ #18 Hwy, 9/34 samples G0.05 @ #18 Hwy, 12/34 samples G0.03
Aldrin & Dieldrin	0.7 ug/L - MDW	0.7 ug/L drinking water 0.004 ug/L (dieldrin) aquatic life	L0.001 aldrin L0.002 dieldrin ug/L	--
Chlordane (Total Isomers)	7 ug/L - MDW	7 ug/L drinking water 0.006 ug/L aquatic life	Alpha L0.003-0.003 ug/L Gamma L0.002 ug/L	--
2,4-D	0.1 - MDW	0.1 drinking water 4.0 ug/L aquatic life (phenoxy herbicides)	L0.004 - L0.5 ug/L	--
DDT	0.03 - MDW	0.03 drinking water 0.001 ug/L aquatic life	O,P - L0.001 ug/L P,P - L0.004 ug/L	--
Endosulphan	--	0.02 ug/L aquatic life	Alpha L0.001 ug/L Beta L0.003 ug/L	--
Endrin	0.2 ug/L - MDW	0.2 ug/L drinking water 0.0023 ug/L aquatic life	L0.002 ug/L	--
Heptachlor & Heptachlor Epoxide	3 ug/L - MDW	3 ug/L drinking water 0.01 ug/L aquatic life	L0.001 ug/L Heptachlor L0.002 Heptachlor Epoxide	--
Lindane (Gamma-BHC)	4 ug/L - MDW	4 ug/L drinking water	L0.001 - 0.004 ug/L	--
Methoxychlor	0.1 - MDW	0.1 drinking water	L0.01 ug/L	--
Methyl-Parathion	7 ug/L - MDW	7 ug/L drinking water	--	--

TABLE 2.4 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
PCB's (Total)	3 ug/L 0.02 ug/L MDW	0.001 ug/L aquatic life	L0.002 ug/L (Total Aroclors)	--
Coliforms, Total	L5,000/100 mL for potable supply or recreation (not direct contact) for ≥90% of the samples(not ≥5 samples/30-d period) -depends on type and degree of pollution, local conditions in watershed. L1000/100 mL geom. mean of 5 samples for direct contact recreation or vegetable crop irrigation for ≤20% of the samples in one month, or ≤2400/100 mL/day.	1000/100 mL irrigation high quality -livestock	L10 - 900/100 mL(MF) L23 - 4300/100 mL(MP<N) (provincial data)	@ #18 Hwy, 1/115 samples G5000/100 mL, @ #18 Hwy, 6/115 samples G2400/100 mL, @ #18 17/115 samples G1000/100 mL.
Coliforms, Fecal	L1000/100 mL (see above) L200/100 mL (see above)	--	L10-190/100 mL (MF) L23-12045/100 mL(MPN) (provincial data)	@ #18 Hwy, 5/117 samples G1000/100 mL @ #18 Hwy, 20/117 samples G200/100 mL
pH	6.5 - 8.5 but not 0.5 units over background value	6.5 - 8.5 drinking water 5.0 - 8.3 cooling water	7.4 - 9.3(field)	@ #18 Hwy, 14/102 samples G8.5, 4/102 samples G 8.3
Colour	≤30 TCU increase above natural value	15 TCU drinking water	30 - 225 relative units	Values tend to be higher in sp and sum, lower in w.
Turbidity	≤25 NTU over natural turbidity	5 NTU drinking water	4 - 190 JTU	Values tend to be higher in sp and sum, lower in w.
Temperature	≤3°C increase above ambient water temp.	15°C drinking water No alterations of thermal stratification or turn-over dates; no exceedences of max weekly ave temp, and no exceedences of max short-term temp.	18 - 22(summer)	

Notes: Objectives/guidelines denote "less than or equal to" values unless otherwise stated.

[1] Saskatchewan Environment Water Quality Objectives, 1983 (Surface Water Quality Objectives)
Saskatchewan Environment Municipal Drinking Water Quality Objectives, June 1980 (MDW)

[2] Canadian Council of Resource and Environment Ministers - Canadian Water Quality Guidelines, March 1987

[3] Observed Ranges - # signifies median ranges.

steep banks at the downstream end and stable low relief topography at the upper end. The reservoir has a volume of approximately 60,500 m^3 at FSL and a surface area at the same elevation of 599 ha. The mean depth at FSL is described as 10 m, but at the north end it is 22 m. (Saskatchewan Environment 1983)

Water quality and the aquatic environment in Long Creek is moderated by the presence of the instream reservoir and by the major purpose of the reservoir--use as a cooling pond for the 882 megawatt thermal generating station and as a receiving body for settled ash lagoon effluents.

The operation of the Boundary Dam Power Station requires large volumes of cooling water which results in a number of theoretical annual turnover cycles for the reservoir. Due to the configuration of the reservoir, most of the cooling water recycling occurs near the downstream end. This operation produces warm summer water temperatures and ice free conditions near the dam during the winter.

The other major user of the reservoir is the City of Estevan, which utilizes Long Creek as its water supply source. In 1985 a direct pipeline from the riparian outlet at Boundary Dam was constructed directly to the water treatment plant. Other uses include some limited commercial irrigation and, on Boundary Reservoir, recreational development. Point sources of wastewater effluents to Boundary Reservoir and the lower reach of Long Creek are essentially limited to the cooling water return and settled ash lagoon effluents from the generating station and water treatment plant wastewater from the City's facility located adjacent to the creek.

The critical operations of Boundary Reservoir are essentially governed by the needs of the generating station.

.2 Water Quality Observations

Data for Boundary Reservoir and the lower reach of Long Creek were obtained from the federal and provincial data bases, the City of Estevan, and from reports undertaken by Saskatchewan Environment and those for the Saskatchewan Power Corporation relative to Boundary Reservoir. General observations respecting various parameter groupings follow:

a) Dissolved Salts

- Seasonal medians and 25th and 75th percentiles of conductance for the lower portion of Boundary Reservoir opposite the generating station's intake to the mouth are shown on Figure 2.11. Typically minor increases from the spring through the winter seasons occur, probably a reflection of the dilution from spring runoff. Available data suggest that fall and winter values at the mouth are considerably higher (1000 to 1100 uS/cm) than at the upstream stations. It is unknown if this is due to the relative sampling times and frequency, the effects of ice concentration in the lower reach of Long Creek, and/or the infusion of other discharges such as groundwater. Mean values during the spring through fall period in Boundary Reservoir and immediately below typically range from about 650 uS/cm to 750 uS/cm. Within the reservoir, variations of the 25th and 75th percentile exist and probably mirror the hydrological regime during the period of sampling.
- Chloride tended to follow the same pattern as conductance for the 3 sites. Although chloride values are relatively low in Boundary Reservoir (medians of L20 mg/L) the seasonal variations are evident.(Figure 2.12)
- Based on an assessment of the ionic species, sodium and sulphate are the predominant cations and anions respectively. Sodium could account for 40% to 55% of the cations while sulphate could account from 50% to in excess of 65% of the anions in Boundary Reservoir. SAR values during the spring through fall months range from 2.1 to 4.5 in the reservoir and from 2.7 to 3.6 in the creek below Boundary. Sodium trends are shown on Figure 2.13.

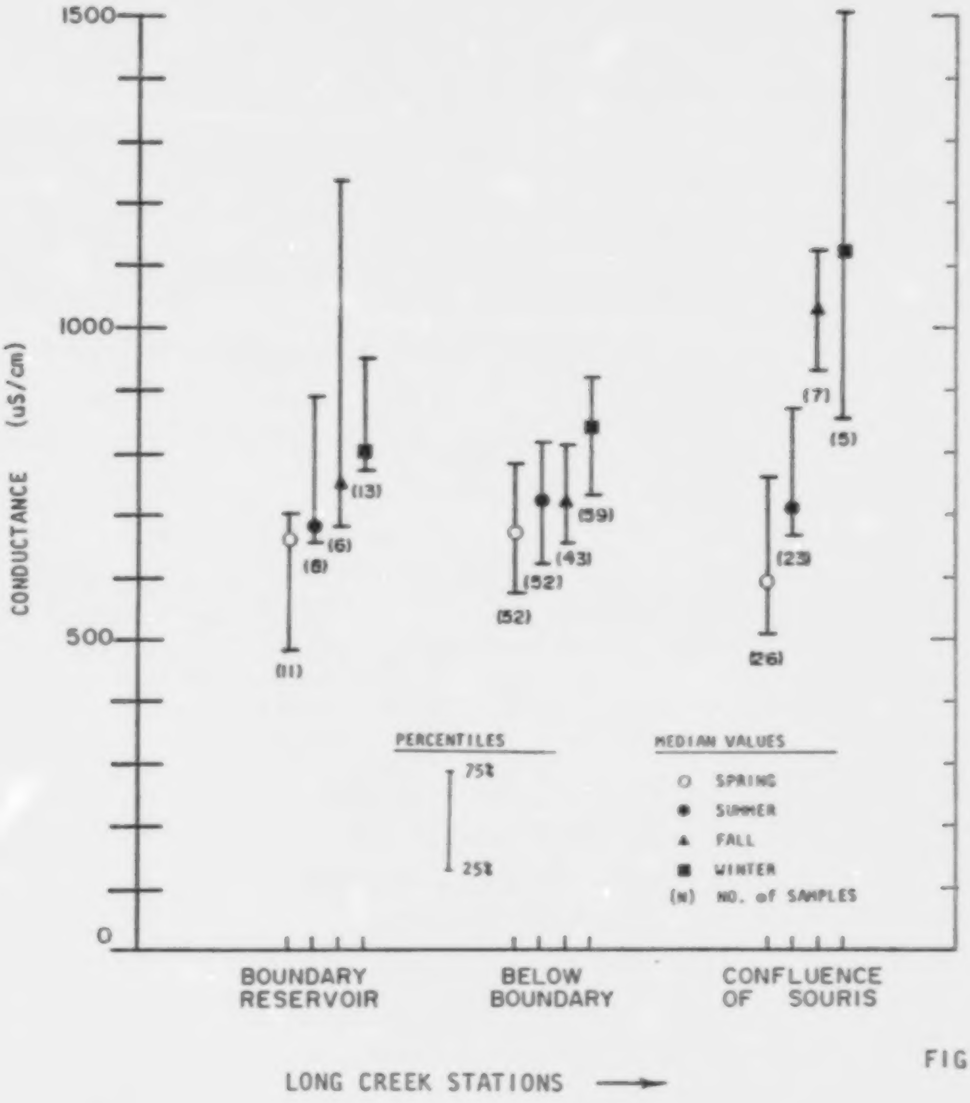

1500
1000
500
0
CONDUCTANCE (uS/cm)
(11)
(8)
(6)
(13)
(52)
(52)
(43)
(59)
(26)
(23)
(7)
(5)
PERCENTILES
75%
25%
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
BOUNDARY RESERVOIR
BELOW BOUNDARY
CONFLUENCE OF SOURIS
LONG CREEK STATIONS →

FIG. 2.11

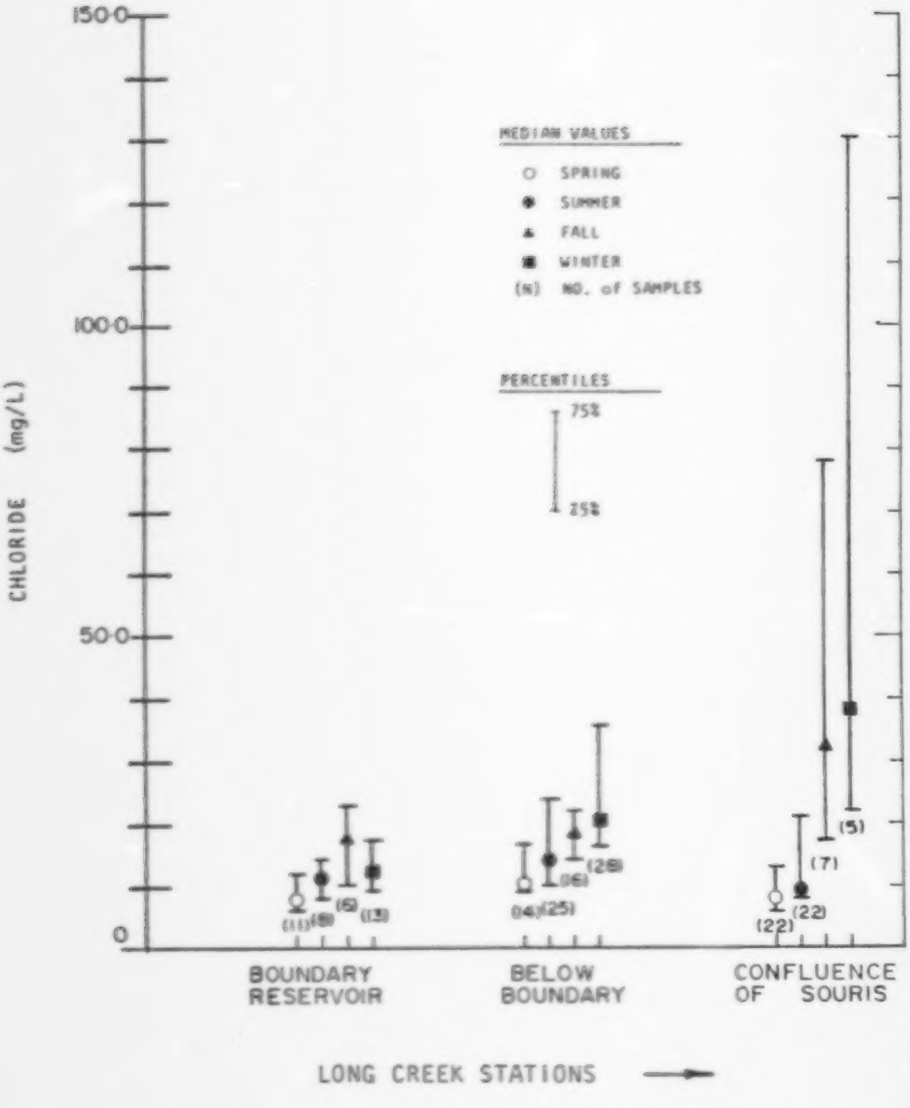

150·0
100·0
50·0
0
CHLORIDE (mg/L)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
(11)
(8)
(6)
(13)
(14)
(25)
(16)
(28)
(22)
(22)
(7)
(5)
BOUNDARY RESERVOIR
BELOW BOUNDARY
CONFLUENCE OF SOURIS
LONG CREEK STATIONS →

FIG. 2.12

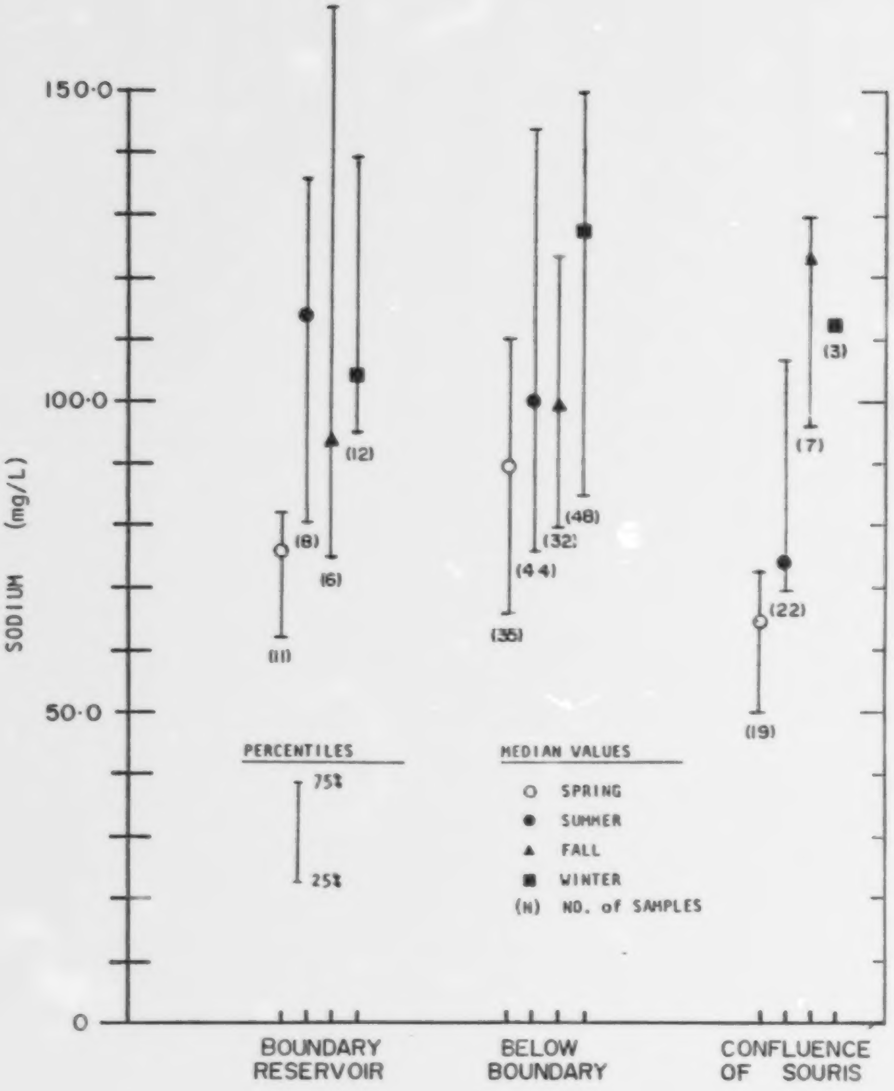

150·0
100·0
50·0
0
SODIUM (mg/L)
(11)
(8)
(6)
(12)
(35)
(44)
(32)
(48)
(19)
(22)
(7)
(3)
PERCENTILES
75%
25%
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
BOUNDARY RESERVOIR
BELOW BOUNDARY
CONFLUENCE OF SOURIS
LONG CREEK STATIONS →

FIG. 2.13

b) Nutrients

- Phosphorus levels in Boundary Reservoir tended to remain fairly consistent and do not fluctuate substantially with seasons. Typical median values for total phosphorus in the reservoir and below the reservoir is 0.1 mg/L (Figure 2.14).
- Nitrogen demonstrates much more variability than phosphorus. As noted from Figure 2.15, TKN values fluctuate considerably in the system, although the medians were relatively consistent. No major seasonal pattern emerges. Median values of 0.8 to 1.0 TKN were observed in the reservoir.

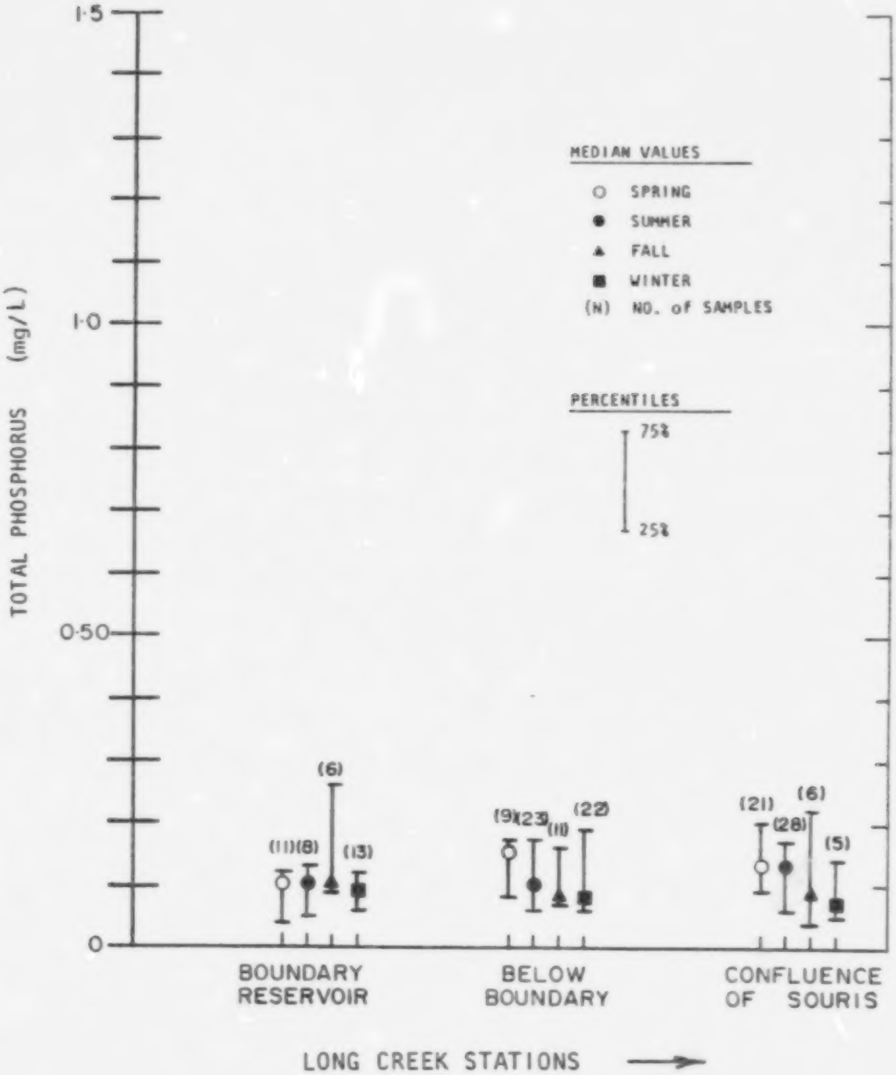


FIG. 2.14

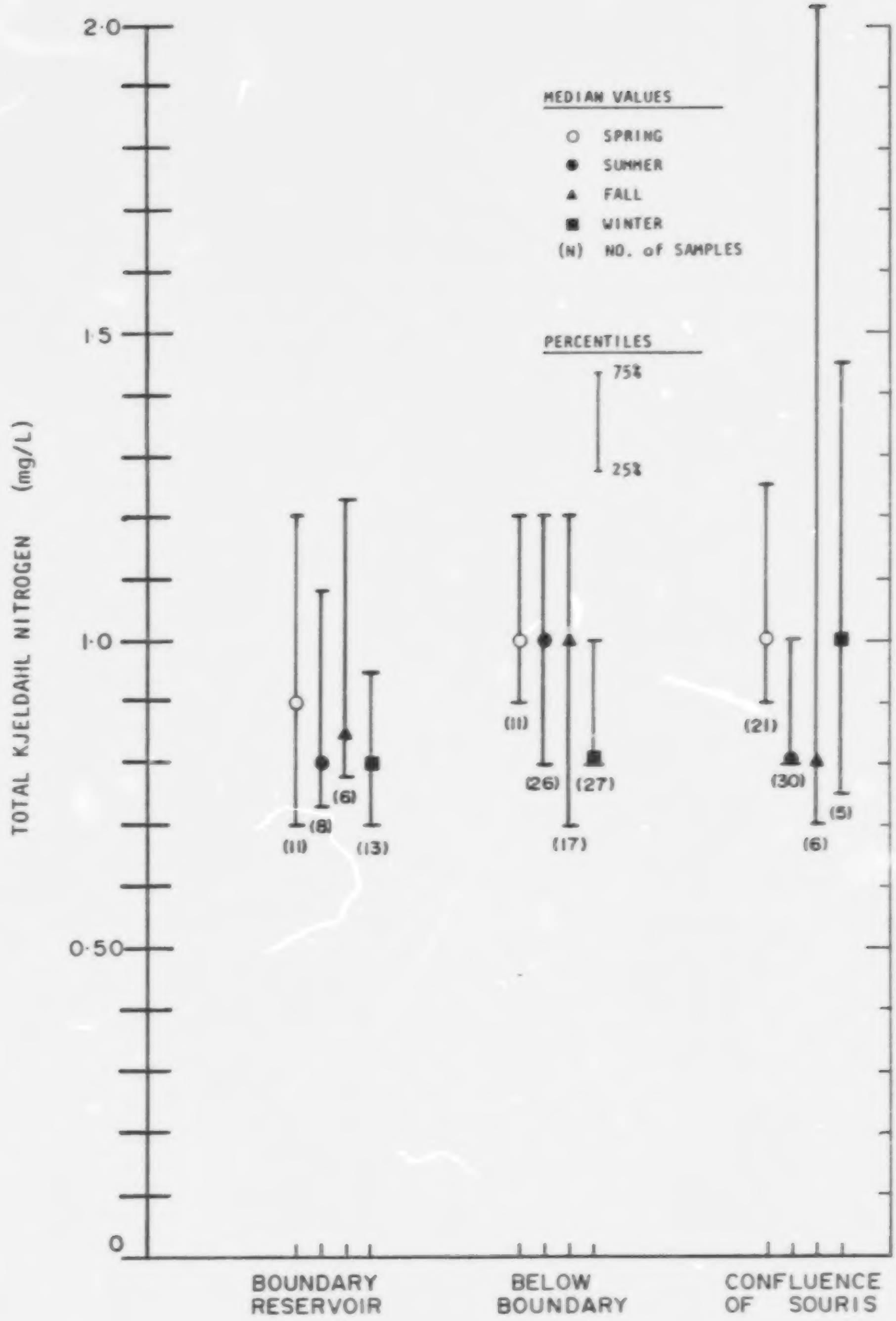

2·0
1·5
1·0
0·50
0
TOTAL KJELDAHL NITROGEN (mg/L)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
(11)
(8)
(6)
(13)
(11)
(26)
(27)
(17)
(21)
(30)
(5)
(6)
BOUNDARY RESERVOIR
BELOW BOUNDARY
CONFLUENCE OF SOURIS
LONG CREEK STATIONS →

FIG. 2.15

Higher variations have been recorded in the TKN readings near the mouth, particularly during the fall and winter period, but the exact causes are undefined. A similar observation was made for conductance.

c) Dissolved Oxygen

. Most of the dissolved oxygen data is from Boundary Reservoir or from Long Creek immediately below the reservoir. As noted on Figure 2.16, the median values for dissolved oxygen at these stations tended to be 7 mg/L or greater during all seasons. Typically summer values were at a low, perhaps due to high water temperatures, and were much greater during the spring, fall, and winter periods. Variations do not indicate major inputs through photosynthesis, i.e. supersaturation. Depth oxygen profiles indicate considerable uniformity at the lower end of the reservoir. For example, February 1983 data range from 9.7 to 9.9 mg/L throughout the entire 14 m depth.(Saskatchewan Environment 1983) At the time, temperatures were 9.5 °C at all levels.

d) Heavy Metals/Trace Substances

. Only a limited number of data are available for Long Creek above Boundary Reservoir. These data indicate variability with respect to aluminum, arsenic, boron, copper, and cyanide. Within the reservoir, a number of water column samples have been collected for various heavy metals and trace substances. Generally mean concentrations were below the level of detection, and some metals are consistently below detection levels (silver, vanadium, lead, copper, and cadmium). Of potential interest are concentrations of aluminum, arsenic, barium, boron, and fluoride. The mean concentration of boron was reported at 0.49 mg/L.(Saskatchewan Environment 1983) That same report noted that samples collected at various sites during the winter of 1983 indicated some variations in parameters' concentrations (some higher values were encountered at the deeper depth, i.e. selenium and lead), but generally there is no significant vertical variations observed. Fluoride concentrations in the order of 1 mg/L have been recorded. Heavy metals and trace substances data for Long Creek are summarized in Table 2.5.

. Sediment analyses have been carried out for a number of variables and these have been reported by Saskatchewan Environment (1983). Mercury analyses have been the most prevalent. Main ranges of sediments were from 66 to 77 ppb dry weight. Other metals have been detected in the

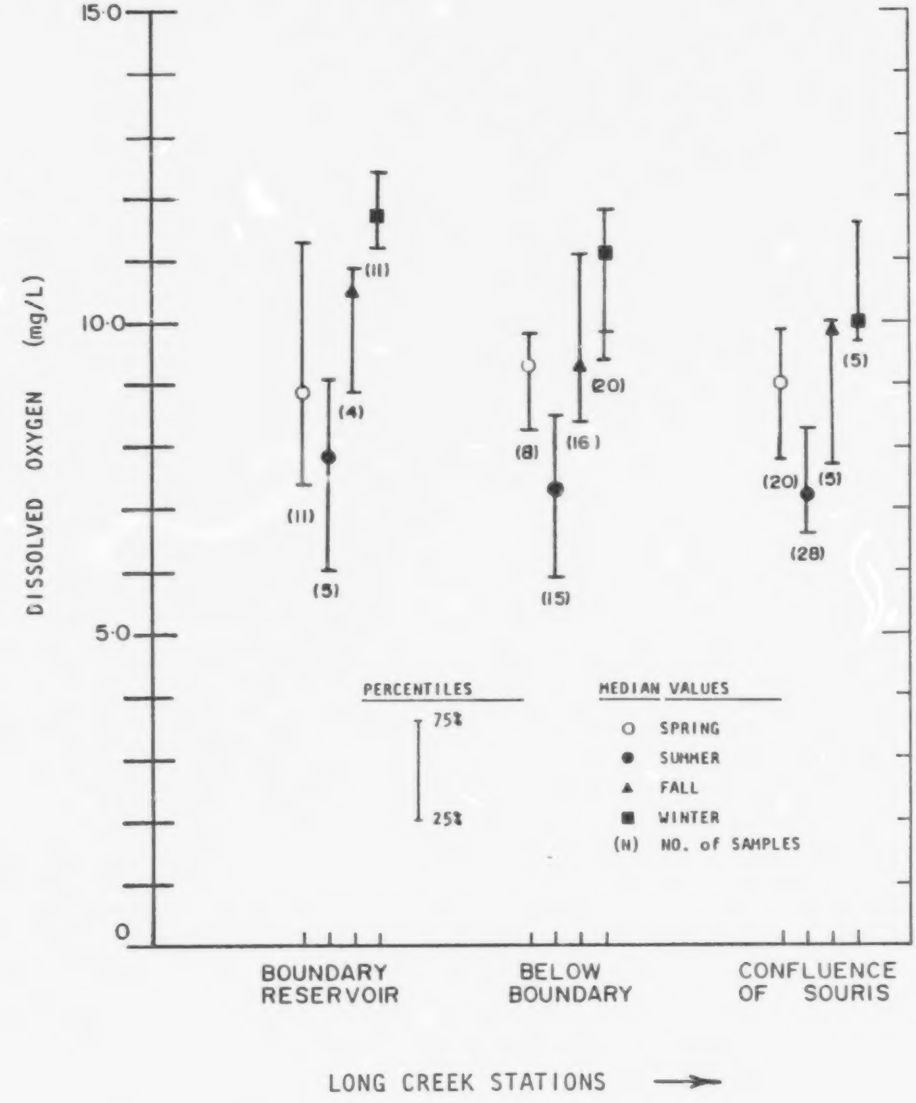

15·0
10·0
5·0
0
DISSOLVED OXYGEN (mg/L)
(11)
(5)
(4)
(11)
(8)
(15)
(16)
(20)
(20)
(28)
(5)
(5)
PERCENTILES
75%
25%
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
BOUNDARY RESERVOIR
BELOW BOUNDARY
CONFLUENCE OF SOURIS
LONG CREEK STATIONS →

FIG. 2.16

TABLE 2.5
HEAVY METALS/TRACE SUBSTANCES
EXISTING QUALITY SUMMARY
Long Creek

Parameter	Form	Station	Data Base Period	Samples	Seasonal Distr. Sp	Su	F	W	Range (mg/L unless noted)	Comments
Al	E	L014	Jan 09/79 to May 28/86	25	1	5	8	11	0.02 - 2.5	
	T	B003	Jan 09/79 to Jan 12/8	3	0	0	0	3	0.24 - 1.2	
	T	L013	Mar 03/80 to Aug 09/81	3	0	2	0	1	0.11 - 3.9	
As	T	L019	Jun 12/81 to Nov 22/82	3	1	1	1	0	0.002 - 0.008	
	D	L014	Jan 09/79 to Mar 4/85	32	7	5	8	12	0.006 - 0.014	
	T	B003	Jan 09/79 to Jan 12/81	3	0	0	0	3	0.006 - 0.007	
	D	B003	Mar 16/75 to Feb 09/76	11	6	2	0	3	0.0019 - 0.0048	
	T	L018	Jan 19/82 to Nov 22/82	5	1	1	1	2	0.0024 - 0.013	
	T	L013	Mar 3/80 to Oct 27/81	3	0	1	1	1	0.0004 - 0.018	
Ba	T	B003	Jan 12/81	1	0	0	0	1	0.03	
Be	T	B003	Jan 12/81	1	0	0	0	1	0.02	
	E	B003	Jul 28/75 to Feb 09/76	5	1	1	0	3	L0.01	
B	D	L019	Jun 12/81 to Nov 22/82	3	1	1	1	0	0.67 - 0.87	
	D	L014	Jan 09/79 to Mar 04/85	26	2	5	8	11	0.02 - 2.9	
	D	B003	Jan 09/79 to Jan 12/81	6	0	0	0	6	0.25 - 1.3	
	D	L018	Jan 19/82 to Nov 22/82	5	1	1	1	2	0.07 - 0.55	
	D	L013	Mar 03/80 to Oct 27/81	4	0	2	1	1	0.07 - 0.80	
Cd	T	L019	Jun 12/81	1	1	0	0	0	L0.02	
	E	L019	Apr 19/75 to Oct 26/77	21	7	7	4	3	L0.001 - 0.002	13 @ L0.001
	E	L014	Oct 31/78 to Mar 4/85	28	5	4	9	10	L0.001 - 0.03	3 @ L0.1, 7 @ L0.02 11 @ L0.001, 4 @ L0.005
	T	B003	Oct 17/77 to Jan 12/81	6	0	0	2	4	L0.02 - L0.1	2 @ L0.02 4 @ L0.1
	E	B003	Mar 16/75 to Feb 09/76	11	6	2	0	3	L0.001 - 0.002	5 @ L0.001
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	0.001	2 @ L0.002 1 @ L0.1
Cr	T	L019	Jun 12/81	1	1	0	0	0	0.003	
	E	L019	Apr 24/75 to Jan 18/78	19	5	7	4	3	L0.015	
	E	L014	Oct 31/78 to May 28/86	29	5	4	9	11	L0.001 - 0.015	1 @ L0.001 1 @ L0.002
	T	B003	Oct 17/77 to Jan 12/81	5	0	0	2	3	0.001 - 0.012	
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	L0.015	
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	0.005 - 0.012	1 @ L0.001

TABLE 2.5 (Cont'd)

Parameter	Form	Station	Data Base Period	Samples	Seasonal Distr. Sp	Su	F	W	Range (mg/L unless noted)	Comments
Co	E	L019	Jun 19/75 to Jan 18/78	17	3	7	4	3	L0.002 - 0.004	10 @ L0.002
	E	B003	Jul 28/75 to Feb 09/76	5	2	0	0	3	L0.002 - 0.003	3 @ L0.002
	T	B003	Oct 17/77 to Oct 31/78	2	0	0	2	0	L0.003	
	T	L013	Oct 31/78 to Aug 09/81	2	0	1	1	0	L0.003 - 0.003	1 @ L0.003
	T	L014	Oct 21/81 to Mar 04/85	13	3	1	4	5	L0.001 - 0.001	12 @ L0.001
	E	L014	Jan 15/74 to Jan 30/75	4	0	1	1	2	L0.001 - 0.005	1 @ L0.001
Cu	T	L019	Jun 12/81	1	1	0	0	0	0.002	
	E	L019	Apr 24/75 to Jan 18/78	19	4	8	4	3	L0.001 - 0.070	1 @ L0.001
	E	L014	Oct 31/79 to Mar 04/85	27	4	5	8	10	L0.002 - 0.07	1 @ L0.011 1 @ L0.002
	T	B003	Oct 17/77 to Oct 28/81	6	0	0	2	4	L0.002 - 0.018	2 @ L0.1 1 @ L0.002
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	0.006 - 0.080	
CN^-	D	L014	Feb 21/79 to Mar 4/85	25	5	2	8	10	0.000 - 0.027	5 @ L0.1 1 @ L0.5
	D	L013	Mar 03/81 to Jun 22/81	2	0	1	0	1	0.007 - 0.028	
F	D	L019	Jun 12/81 to Nov 03/86	6	2	2	2	0	0.3 - 1.2	
	D	L019	Apr 19/75 to Jan 18/78	44	20	17	4	3	0.05 - 0.34	
	D	L014	Aug 24/81 to Mar 04/85	25	2	10	6	7	0.3 - 1.2	
	D	B003	Apr 4/75 to Feb 9/76	12	6	3	0	3	0.06 - 0.2	
	D	L018	Jan 19/82 to Nov 22/82	5	1	1	1	2	0.1 - 0.5	
	D	L013	Aug 14/81 to Oct 27/81	3	0	2	1	0	0.1 - 0.7	
Fe	T	L019	Apr 13/81 to May 30/86	7	2	2	1	2	0.2 - 0.8	
	E	L019	Apr 16/75 to Feb 09/76	11	6	2	0	3	0.04 - 0.69	
	T	L014	Jan 25/77 to May 28/86	63	9	17	13	24	L0.1 - 5.0	4 @ L0.1
	E	L014	Aug 24/73 to Jan 30/75	6	0	2	2	2	0.07 - 0.21	
	T	B003	Jan 15/75 to Feb 14/84	28	5	7	7	9	L0.1 - 1.7	3 @ L0.1
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	0.04 - 0.69	
	T	L018	Mar 10/82 to Feb 28/83	2	0	0	0	2	0.3 - 2.3	
	T	L013	Oct 31/78 to Oct 27/81	7	1	3	2	1	0.1 - 1.3	
Pb	T	L019	Jun 12/81	1	1	0	0	0	L0.002	
	E	L019	Apr 24/75 to Jan 18/78	19	4	8	4	3	L0.002 - 0.080	16 @ L0.004 1 @ L0.002
	E	L014	Oct 31/78 to Mar 04/85	29	4	5	9	11	L0.001 - 0.12	1 @ L0.001 9 @ L0.005 8 @ L0.002
	T	L014	Aug 07/79 to Mar 4/85	24	3	5	8	8	L0.002 - 0.036	6 @ L0.002 9 @ L0.005

TABLE 2.5 (Cont'd)

Parameter	Form	Station	Data Base Period	Samples	Seasonal Distr. Sp	Su	F	W	Range (mg/L unless noted)	Comments
	T	B003	Oct 17/77 to Oct 28/81	6	0	0	2	4	L0.002 - 0.007	1 @ L0.1 3 @ L0.002
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	L0.004 - 0.008	6 @ L0.004
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	L0.002 - 0.021	2 @ L0.002
Mn	T	L019	Apr 13/81 to Nov 03/86	8	2	2	2	2	L0.1 - 0.18	1 @ L0.1
	E	L019	Apr 24/75 to Jan 18/78	19	4	8	4	3	0.02 - 0.28	
	T	L014	Jan 25/77 to May 28/86	69	11	19	15	24	L0.01 - 0.59	16 @ L0.01
	D	L014	Jun 16/72 to Mar 06/73	4	0	2	0	2	L0.01 - 0.13	2 @ L0.01
	E	L014	Aug 24/73 to Jan 30/75	6	0	2	2	2	0.03 - 0.10	
	T	B003	Jan 15/75 to Feb 14/84	25	5	5	6	9	L0.01 - 0.13	3 @ L0.01
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	0.01 - 0.04	
	T	L018	Mar 10/82 to Feb 28/83	2	0	0	0	2	0.17 - 4.4	
	T	L013	Oct 31/78 to Oct 27/81	7	0	4	2	1	0.01 - 3.03	
Hg	E	L019	Jun 05/75 to Jan 18/78	16	3	7	4	2	L0.02 - 0.10 (ug/L)	9 @ L0.05 4 @ L0.02
	T	L014	Oct 31/78 to Mar 04/85	26	3	3	9	11	L0.02 - 0.15 (ug/L)	9 @ L0.1, 1 @ L0.05 8 @ L0.02
	E	L014	Aug 24/73 to Jan 30/75	5	0	2	2	1	L0.05 - 0.06 (ug/L)	4 @ L0.05
	T	B003	Oct 17/77 to Oct 28/81	7	0	0	3	4	L0.02 - 0.15 (ug/L)	3 @ L0.1 1 @ L0.02
	E	B003	May 22/75 to Jul 28/75	4	2	2	0	0	L0.05	
	T	L013	Oct 31/78 to Jun 22/81	3	0	1	1	1	0.05 - L0.1 (ug/L)	2 @ L0.1
Mo	E	L019	Jun 19/75 to Aug 30/76	7	1	4	1	1	L0.10	
	E	L014	Jun 08/82 to May 28/86	13	4	0	5	4	0.01 - 0.04	
Ni	T	L019	Jun 12/81	1	1	0	0	0	0.007	
	E	L019	Oct 31/78 to Mar 04/85	26	3	4	8	11	L0.001 - 0.04	7 @ L0.005 2 @ L0.001
	T	B003	Oct 17/71 to Jan 12/81	6	0	0	2	4	L0.005 - 0.010	2 @ L0.005 1 @ L0.1
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	L0.005 - 0.03	1 @ L0.005
Se	T	L014	Jan 09/79 to Mar 04/85	12	3	0	4	5	L0.001 - 0.008	2 @ L0.001
	D	L014	Jul 26/74 to Jan 30/75	3	0	1	1	1	0.0007 - 0.0013	
	T	B003	Jan 09/79 to Jan 12/81	3	0	0	0	3	L0.0001 - 0.0006	1 @ L0.0001
	D	B003	Apr 16/75 to Feb 09/76	9	6	0	0	3	0.0009 - 0.0023	
Si	T	L014	Nov 27/82 to Mar 24/85	5	1	0	2	2	L0.01 - 0.08	1 @ L0.01 2 @ L0.05
Ag	T	L014	Feb 21/79 to Mar 4/85	20	3	3	5	7	L0.001	5 @ L0.01 15 @ L0.001
	T	B003	Oct 17/77 to Jan 12/81	3	0	0	1	2	L0.01	1 @ L0.01 2 @ L0.1

TABLE 2.5 (Cont'd)

			Data Base							
					Seasonal Distr.					
Parameter	Form	Station	Period	Samples	Sp	Su	F	W	Range (mg/L unless noted)	Comments
Tl	T	L014	Nov 22/82 to Mar 4/85	11	2	0	5	4	L0.001 - 0.024	3 @ L0.001
W	T	L014	Nov 22/82 to Mar 4/85	11	2	0	5	4	L0.005 - 0.01	6 @ L0.005
U	T	L014	Aug 23/82 to Mar 04/85	11	2	1	4	4	1.0 - 11 (ug/L)	
	T	L018	Aug 23/82	1	0	1	0	0	6.8 (ug/L)	
V	T	L014	Jan 09/79 to Mar 04/85	13	3	0	5	5	L0.01 - 0.01	5 @ L0.01
	T	B003	Jan 09/79 to Jan 22/80	2	0	0	0	2	L0.01	
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	L0.001 - 0.005	2 @ L0.001
	T	L013	Aug 09/81	1	0	1	0	0	0.04	
Zn	T	L019	Jun 12/81	1	1	0	0	0	0.04	
	E	L019	Jun 05/75 to Jan 18/78	18	3	8	4	3	L0.001 - 0.009	6 @ L0.001
	E	L014	Oct 31/78 to Mar 4/85	29	4	5	9	11	0.002 - 0.25	2 @ L0.1, 5 @ L0.01 1 @ L0.05
	T	B003	Oct 17/77 to Jan 12/81	6	0	0	2	4	L0.01 - 1.1	2 @ L0.1 1 @ L0.01
	E	B003	Apr 16/75 to Feb 09/76	11	6	2	0	3	L0.001 - 0.010	1 @ L0.001
	T	L013	Oct 31/78 to Aug 09/81	4	0	2	1	1	0.02 - 0.04	1 @ L0.1

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

sediments, although cadmium, lead, and silver are either at or below detection levels. The comparison of Boundary Reservoir data with other available prairie lakes and reservoirs do not suggest anything particularly extraordinary for metal sediment levels observed in Boundary Reservoir.(Saskatchewan Environment 1983)

- Fish muscle tissue has been analyzed for mercury. Walleye data from 1974 and 1982 indicated considerable ranges. For example, Walleye in 1974 ranged from 0.11 to 0.64 ppm, while the 1982 data for the same species had a range of from 0.17 to 0.87 ppm.(Saskatchewan Environment 1983)

- Heavy metal and trace substances of algal tissue were also obtained on samples collected March 1, 1983. Generally the concentrations were similar to that observed on surface sediments except for copper and zinc which were several times greater.(Saskatchewan Environment, 1983)

e) Biocides and Organochlorine Compounds

- Most of the biocide data from Boundary Reservoir originates from the Souris River Basin Study (1978). A number of parameters were tested of the organochlorine group including PCBs. The only positive detections at the time were with 2,4-D, 2,4,5-T, and lindane. Mean values were 0.1, 0.002, and 0.001 ug/L respectively.

- In Long Creek below the reservoir, the positive detections are largely related to 2,4-D, alpha-BHC, and lindane. Maximum values reported were 0.013 ug/L for 2,4-D, 0.007 ug/L for alpha-BHC, and 0.004 ug/L for lindane. Biocide and organochlorine compound data for below Boundary Reservoir are summarized in Table 2.6.

f) Bacteriology

- Available data for the indicator coliform bacteria group suggest low levels of detections in Boundary Reservoir and at Long Creek below the dam. Median levels were typically less than 100 total coliforms per 100 mL. Fecal coliform data tended to have medians at 10 per 100 mL or less. Because of the thermal nature of the reservoir, there has been some concern with respect to the potential for other organisms to grow, but data are unavailable to support or better describe this potential.(Saskatchewan Environment 1983)

g) Miscellaneous Parameters

- Limited radionuclide data are available for Long Creek immediately above and below the reservoir. Tested were ^{222} Ra, gross beta and gross alpha emitters, ^{90} Sr, ^{137} Cs and ^{131} I. All except ^{226} Ra, which was at 0.01 becquerels/L, were determined to be less than detection limits.

TABLE 2.6

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Long Creek (Below Boundary Reservoir)

Parameter	Data Base						Range (ug/L unless noted)	Comments
	Period	Samples	Seasonal Distr.					
			Sp	Su	F	W		
2,4-D	Oct 31/78 to Mar 04/85	20	1	6	7	6	L0.004 - 0.148	3 @ L0.5 10 @ L0.004
2,4-DB	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.009	
2,4-DP	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.004	
2,4,5-T	Oct 31/78 to Mar 04/85	20	1	6	7	6	L0.002 - 0.034	1 @ L2.5 2 @ L0.25 16 @ L0.002
MCPA	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.2	
Silvex	Oct 01/79 to Mar 04/85	14	0	5	5	4	L0.004	
Diclofop	Jun 18/84 to Mar 04/85	2	0	1	0	1	L0.05	
Tri-Allate	Jun 18/84 to Mar 04/85	2	0	1	0	1	L0.01	
Trifluralin	Jun 18/84 to Mar 04/85	2	0	1	0	1	L0.005	
Alpha-BHC	Oct 01/79 to Mar 04/85	16	0	5	6	5	0.001 - 0.009	
Gamma-BHC	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001 - 0.004	5 @ L0.001
Alpha-Chlordane	Jan 22/80 to Mar 04/85	15	0	5	5	5	L0.003	
Gamma-Chlordane	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.002	
Dieldrin	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.002	
Alpha-Endosulfan	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
Beta-Endosulfan	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.003	
Endrin	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.002	
Heptachlor	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
Heptachlor Epoxide	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.002	
Hexachlorobenzene	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
O,P-DDT	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
P,P-DDT	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
P,P-DDD	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
P,P-DDE	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
P,P-Methoxychlor	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.01	
Mirex	Oct 01/79 to Mar 04/85	16	0	5	6	5	L0.001	
Aroclor 1242 (PCB's)	Aug 4/81 to Nov 22/82	4	0	3	1	0	L0.002	
Aroclor 1248 (PCB's)	Oct 1/79 to July 2/80	3	0	1	1	1	L0.002	
Aroclor 1254 (PCB's)	Oct 1/79 to Nov 22/82	7	0	4	2	1	L0.002	
Aroclor 1260 (PCB's)	Oct 1/79 to Nov 22/82	7	0	4	2	1	L0.005	
Aroclor Total (PCB's)	Jan 22/80 to Mar 4/85	11	0	5	3	3	L0.002	2 @ L0.02 9 @ L0.002

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

- Turbidity and suspended solids have also been reviewed at Boundary Reservoir.(Saskatchewan Environment 1983) Within the lower part of the reservoir, turbidity values have a range from 4.5 to 21 JTU. Suspended solids values in the lower part have ranged up to 124 mg/L. The City of Estevan has noted considerable variations in raw water turbidity on a short temporal frequency. It is assumed that the large volume of pumping for cooling water purposes at the generating station induces considerable circulation, which could be manifested in varying turbidity values.

- Colour has also been reported in the reservoir. Apparent colour values as high as 80 (platinum cobalt units) have been observed, although mean units near the north end and near the elbow at the public beach have been 34 and 37 units respectively.(Saskatchewan Environment 1983)

h) Aquatic Biology

- Biological parameters, including phytoplankton, zooplankton, benthos, macrophytes, and fish have been studied in some detail for Boundary Reservoir.(Sawchyn et al. 1977, Souris River Basin Study 1978) Additionally, Saskatchewan Environment (1984) has reported on qualitative phytoplankton observations. Essentially, all of the aquatic biological data for Long Creek has been confined to Boundary Reservoir. The reservoir, due to its morphometry with shallow areas at the upper end and deep areas and steep littoral zones at the north or downstream end can be divided into two distinct habitats.

- The reservoir has exhibited typical eutrophic phytoplankton patterns of seasonal variations. Spring and fall are frequently characterized by a population predominated by diatoms. The main species observed include *Asterionella formosa, Melosira* sp., *Navicula* sp., and *Stephanodiscus niagarae* (Sawchyn et al. 1977, Souris River Basin Study 1978, Saskatchewan Environment 1983).

- During the summer, phytoplankton populations were characterized by tremendous growths of blue-green algae resulting in blooms during July, August, and September. Of the blue-green algae, *Aphanizomenon flos-aquae* predominates and is particularly pronounced at the south end of the reservoir. The central and northern areas of the reservoir have exhibited significantly lower populations due to the much greater water depth.(Sawchyn et al. 1977, Souris River Basin Study 1978) Other potential bloom forming species of these types of algae, *Microcystis aeruginosa* and *Anabaena* *flos-aquae* have been observed but rarely in abundance. Other species identified include *Coelosphaerium* sp. and *Oscillatoria* sp.

- Green algae have tended to maintain relatively stable populations throughout the year. Predominant species identified include *Ankistrodesmus falcatus, Coelastrum microporum,* as well as several species of *Oocystis* and *Scenedesmus.*

- Both chlorophyll analyses (Sawchyn et al. 1977, Souris River Basin Study 1978) and primary production determinations (Sawchyn et al. 1977) reflected similar trends to that of phytoplankton with the highest values found in the south end of the reservoir. Summer primary production rates were highest in the summer due to the algal blooms. Diversity indices for phytoplankton (Souris River Basin Study 1978) showed an increasing trend downstream indicating water of poor quality in the south end and relatively good quality in the north where the water is deep.

- Zooplankton populations have tended to be dominated by two groups of the Crustacea--Cladocera and Copepoda.(Sawchyn et al. 1977, Souris River Basin Study 1978) Representatives of the Acarina and Rotifera are also frequently observed. Zooplankton populations have not correlated well with phytoplankton.(Souris River Basin Study 1978) Populations have been relatively low throughout the reservoir and in some cases their peak numbers were reached when phytoplankton populations were low. The diversity indices for the zooplankton were lowest in the north end in contrast to that observed for phytoplankton. Peak populations for the various groups have been reported for different seasons and different years.(Sawchyn et al. 1977, Souris River Basin Study, 1978) Overall, a general downstream trend has been observed with greater numbers found at the south end of the reservoir.

- Benthic invertebrates have been observed to exhibit a wide variety, although the Oligochaeta and larvae of the Diptera have tended to dominate.(Sawchyn et al. 1977, Souris River Basin Study 1978) Sawchyn et al. (1977) observed a drastic reduction in the Boundary Reservoir benthos from 1975 to 1976 for unknown reasons and found few *Hyalella* sp, which were reported as abundant in a previous study. Other common benthic invertebrates resident in Boundary Reservoir include members of the Amphipoda (side swimmers), Hirudinea (leeches), Nemetoda (roundworms), Hemiptera (bugs), Trichoptera(caddis flies), Coleoptera (beetles), Gastropoda (snails), and Pelecypoda (clams). Members of the Ephemeroptera (mayflies) and the Sphaeriidae, which are typically found in unpolluted waters, were rare throughout

Boundary Reservoir. In concert with other biological groups, the benthic invertebrates exhibited a downstream trend with the greatest numbers and biomass of pollution tolerant organisms found in the south end of the reservoir.(Sawchyn et al. 1977) The bottom sediments were found to be a black and greasy ooze and sometimes with a hydrogen sulphide odour characteristics of highly organic sludges where dissolved oxygen levels are depressed or absent. Benthos diversity indices were low and fairly constant throughout the reservoir.(Souris River Basin Study 1978)

- Aquatic macrophytes or emergent, submergent, or floating aquatic plants have been examined. The downstream or north end does not have a suitable habitat for macrophyte colonization. Stands of cattails (*Typha latifolia)* and a single clump of reedgrass (*Phragmites communis*) were the only emergent vegetation found.(Sawchyn et al. 1977, Souris River Basin Study, 1978) Rooted submergent vegetation was rare and found only in a sheltered bay opposite the recreation area. These included plants of the pondweed group *Potamogeton pectinatus*, *Potamogeton natans*, and *Potamogeton filiformis*.(Sawchyn et al., 1977, Souris River Basin Study, 1978) Floating vegetation has also been observed to be rare and was found to be composed only of uprooted pondweeds. Towards the south end of the reservoir, clumps of sedges (*Scirpus validus*) and cattails, as well as pondweed beds become more extensive. This is consistent with the change in habitat.

.3 Comments

Reasonably comprehensive information exists on the water quality of the lower Long Creek, primarily due to work associated with the Souris River basin study and other studies related to Boundary Reservoir. At the lower end of the reservoir, the water quality is profoundly influenced by the operation of the Boundary Dam Power Station and the use of the reservoir as a source of cooling water and as a receptor for return water and other site effluents. This thermal reservoir maintains warm open water temperatures and in the wintertime is ice free at the lower end. This, together with the large circulation capability of the power station, tends to keep the waters well mixed at the north end.

Based on water quality data, the general quality conditions are reasonably good within the reservoir. The major ions tend to vary with the season and probably reflect the ratio of inflow, evaporative loss, and flushing opportunity. Nutrient levels are low relative to other prairie systems. Based on an historical data review, Allan and Richards (1978) indicated potential TDS fluctuations by as much as 100% in the 6-month period following major runoff and that the spring flush was a major control mechanism for moderating downstream TDS levels. However, aquatic growth can flourish, but the magnitude and persistence of nuisance blooms of blue-green algae are remarkably absent and are not experienced to the same degree to that in other eutrophic systems in the southern part of the province.

Other constituents such as heavy metals, biocides, etc., are present in trace amounts, but generally no use limitations would be prescribed based on available water quality guidelines. Comparisons of corresponding guideline/data parameters for the Reservoir opposite the generating station are summarized in Table 2.7.

With the current use of Boundary Reservoir as a direct source of water for Estevan, it is imperative that the quality be satisfactory to serve as a potable water source.

2.2.3 Souris River - Long Creek to Moose Mountain Creek

.1 General Factors/Use

This 124 km reach of the river is characterized by increasingly better defined river channel and banks, and numerous but short

TABLE 2.7

WATER QUALITY OBJECTIVES AND COMPARISON

SUMMARY GUIDELINES

LONG CREEK

	Water Quality Objectives/Guidelines			
Parameter	Saskatchewan^1 (mg/L unless noted)	CCREM - CWQG^2 (mg/L unless noted)	Observed Ranges^3 (mg/L unless noted)	Comments
Calcium	--	1000 livestock L200 cooling water	37 - 52*	Values tend to be lower in sp; higher in w.
	(Total Hardness - 800 MDW)	--	(Total Hardness as $CaCO_3$ - 220 - 284*)	--
Magnesium	200 - MDW	--	20 - 32*	Values tend to be lower in sp, higher in w.
Sodium	300 - MDW	Depends on crop and soil type for irrigation	73 - 97.5*	Values tend to be lower in sp; higher in w.
-% of cations	30 - 75%	--	--	Range is 39 - 53%.
-SAR	--	Restriction for irrigation: L3 none 3 - 9 slight - moderate G9 severe	--	Range is 2.00 - 4.50
Chloride	250 - MDW	250 drinking water 100 - 700 irrigation L600 cooling water	7.4 - 17*	Values tend to be lower in sp; higher in f.
Bicarbonate	--	L600 cooling water		--
	(Total Alkalinity 500 as $CaCO_3$ - MDW)	--	(Total Alkalinity as $CaCO^3$ - 128 - 206*)	
Sulphate	500 MDW	1000 livestock L680 cooling water	215 - 320*	1/37 samples G500.
TDS (Sum of ions)	1500 MDW	500 drinking water 500 - 3500 irrigation	574 - 767*	21/25 samples G500.
TKN	1.0 (total inorganic and organic N)	10.0 nitrate drinking w 1.0 nitrite 100 NO_3 + NO_2 livestock 10 nitrite 0.06 nitrite - aquatic life	0.8 - 0.9*	10/38 samples G1.0.
Ammonia, Total	--	Depends on temp. and pH	0.03 - 0.12*	Un-ionized ammonia calculated max - 0.012 mg/L.
Phosphorus, Total	0.05 as P	--	0.09 - 0.1*	29/38 samples G0.05.
Oxygen, Dissolved	5.0 min at any time	5.0 - 6.0 warm water 6.5 - 9.5 cold water aquatic biota	7.9 - 11.8*	1/31 samples L5.0.

TABLE 2.7 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Arsenic	0.01	0.05 drinking water and aquatic life 0.1 - 2.0 irrigation (depends on soil) 0.5 livestock (5.0 when not added to feed)	0.0011 - 0.007	--
Barium	1.0	1.0 drinking water	0.03	--
Beryllium		0.1 - 0.5 irrigation (depends on soil) 0.1 livestock	L0.01 - 0.02	--
Boron	0.5	5.0 drinking water 0.5 - 6.0 irrigation (depends on crop) 5.0 livestock	0.25 - 1.3	1/6 samples G0.5.
Cadmium	0.01 0.005 MDW	0.005 drinking water 0.2 - 1.8 aquatic life (depends on hardness) 0.01 irrigation 0.02 livestock	L0.001 - L0.1	4/17 samples L0.1, 2/17 samples L0.02.
Chromium	0.05	0.05 drinking water 0.02 fish; 2.0 aquatic life; 0.1 irrigation 1.0 livestock	L0.001 - L0.015	--
Cobalt		0.05 - 5.0 irrigation (depends on soil) 1.0 livestock	L0.002 - 0.003	--
Copper	0.02	1.0 drinking water 2 - 4 aquatic life (depends on hardness) 0.2 - 1.0 irrigation (depends on crop) 0.5 - 5.0 livestock (depends on animal)	L0.002 - 0.022	2/17 samples G0.02.
Fluoride	1.5 1.5 MDW	1.5 drinking water 1.0 - 15.0 irrigation (depends on soil) 2.0 livestock (1.0 if feed contains fluoride)	0.06 - 0.2	--
Iron	0.3 0.3 MDW	0.3 drinking water 0.3 aquatic life 5.0 - 20.0 irrigation (depends on soil)	0.04 - 1.7	8/36 samples G0.3.
Lead	0.05	0.05 drinking water 1 - 7 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 0.1 livestock	L0.002 - L0.1	--
Manganese	0.05	0.05 drinking water 0.2 - 10.0 irrigation (depends on soil)	L0.01 - L1	3/36 samples G0.05.
Mercury	0.1 ug/L 1 ug/L MDW	1 ug/L drinking water 0.1 ug/L aquatic life 3 ug/L livestock	L0.02 - 0.15 ug/L.	2/12 samples G0.1 ug/L.
Molybdenum	--	0.01 - 0.05 irrigation (depends on soil) 0.5 livestock	--	--

TABLE 2.7 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Nickel	--	25 - 150 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 1.0 livestock	L0.005 - L0.1	--
Selenium	0.01	0.01 drinking water 0.001 aquatic life 0.02 irrigation 0.05 livestock	0.0009 - 0.006	8/12 samples G0.001.
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.01 - L0.1	--
Vanadium	--	0.1 - 1.0 irrigation (depends on soil) 0.1 livestock	L0.001 - L0.01	--
Zinc	0.05	5.0 drinking water 1.0 irrigation, if soil pH L6.5; 5.0, if soil pH G6.5	L0.001 - 1.18	3/17 samples G0.03, 2/17 samples G0.05.
Aldrin & Dieldrin	0.7 ug/L - MDW	0.7 ug/L drinking water 0.004 ug/L (dieldrin) aquatic life	L0.001 aldrin L0.002 dieldrin ug/L	--
2,4-D	0.1 - MDW	0.1 drinking water 4.0 ug/L aquatic life (phenoxy herbicides)	L0.004 ug/L	--
DDT	0.03 - MDW	0.03 drinking water 0.001 ug/L aquatic life	P,P - L0.004	--
Lindane (Gamma-BHC)	4 ug/L - MDW	4 ug/L drinking water	L0.001 ug/L	--
Coliforms, Total	L5,000/100 mL for potable supply or recreation (not direct contact) for ≥90% of the samples (not ≥5 samples/30-d period) -depends on type and degree of pollution, local conditions in watershed. L1000/100 mL geom. mean of 5 samples for direct contact recreation or vegetable crop irrigation for ≤20% of the samples in one month, or ≤2400/100 mL/day.	1000/100 mL irrigation high quality -livestock	L23-90/100 mL* (MPN) L1-100/100 mL* (MF) (provincial data)	--

TABLE 2.7 (Cont'd)

	Water Quality Objectives/Guidelines			
Parameter	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Coliforms, Fecal	L1000/100 mL (see above) L200/100 mL (see above)	--	L23/100 mL* (MPN) L2-20/100 mL* (MF) (provincial data)	1/33 samples G200/100 mL.
pH	6.5 - 8.5 but not 0.5 units over background value	6.5 - 8.5 drinking water 5.0 - 8.3 cooling water	7.5 - 8.4 (field)*	13/28 samples G8.5; 20/28 samples G8.3.
Colour	≤ 30 TCU increase above natural value	15 TCU drinking water	20 - 38 relative units*	--
Turbidity	≤ 25 NTU over natural turbidity	5 NTU drinking water	4.6 - 10.6 JTU*	--
Temperature	≤ 3°C increase above ambient water temp.	15°C drinking water No alterations of thermal stratification or turn-over dates; no exceedences of max weekly ave temp. and no exceedences of max short-term temp.	26°C* (summer)	--

Notes: Objectives/guidelines denote "less than or equal to" values unless otherwise stated.

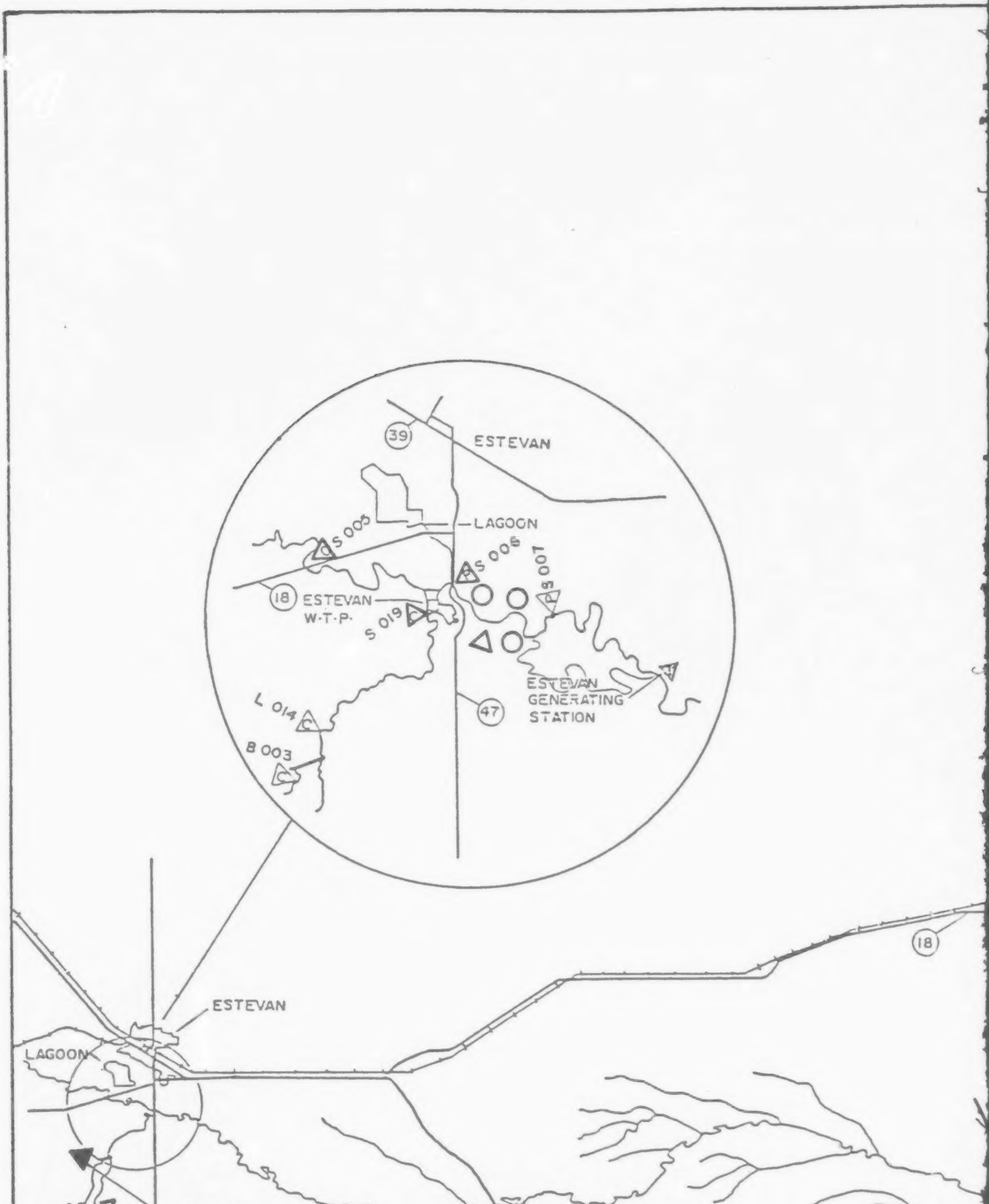
[1] Saskatchewan Environment Water Quality Objectives, 1983 (Surface Water Quality Objectives)
Saskatchewan Environment Municipal Drinking Water Quality Objectives, June 1980 (MDW)

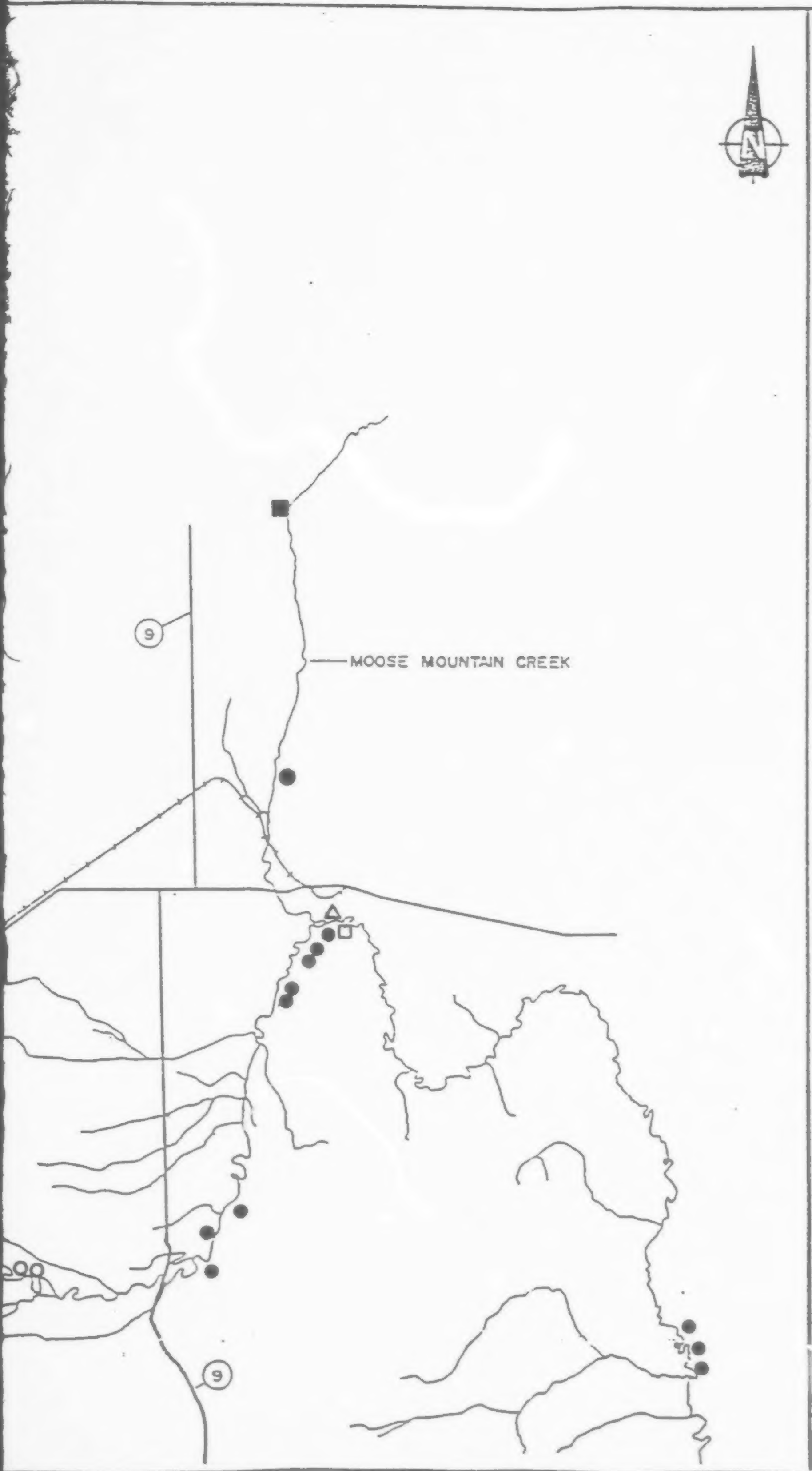
[2] Canadian Council of Resource and Environment Ministers - Canadian Water Quality Guidelines, March 1987

[3] Observed Ranges - * signifies median ranges.

length tributaries. The main tributary is Short Creek. In addition to agricultural practices associated with cultivated and native farmlands, coal mining activity is common in this part of the Souris River valley.

As shown on Figure 2.17, major users would include irrigation (agricultural and commercial), industrial use, and fish and wild life. Primary impacts on water quality would be derived from:


39
ESTEVAN
LAGOON
S 005
S 006
S 007
18
ESTEVAN W.T.P.
S 019
L 014
B 003
47
ESTEVAN GENERATING STATION
18
ESTEVAN
LAGOON
BOUNDARY DAM POWER STATION
RECREATION AREA
BOUNDARY RESERVOIR
47
SOURIS RIVER
SHORT CREEK
39



LEGEND

- □ Municipal use
- ■ Domestic use
- ○ Commercial irrigation
- ● Private irrigation
- ▲ Industrial use
- △ Recreation area

WATER USES

LOWER LONG CREEK

LOWER MOOSE
MOUNTAIN CREEK

SOURIS RIVER
BELOW ESTEVAN

SCALE 1:250 000 FIG. 2.17

M-R-2 — McDONALD & ASSOCIATES

- City of Estevan treated sewage effluent.
- City of Estevan urban runoff.
- Estevan Generating Station activities.
- Direct and indirect drainage from coal mining operations.
- Agricultural runoff including cattle watering activities.

For this reach, the City of Estevan is presently the only municipality known to have a direct effluent discharge to the river. A communal sanitary sewage works is contemplated for the Village of Roche Percee, but the exact nature of the sewage treatment facilities is unknown. Estevan utilizes a conventional sewage lagoon for its treatment. The lagoon consists of 5 primary cells with a total surface area of approximately 27.7 ha (68.5 acres) and 5 secondary lagoon cells with a 30.4-ha (75-acre) surface area and a capacity of approximately 627,350 m^3 (138 million gallons). The last improvements and construction to the Estevan facility were completed in 1974. Effluent discharge is to the southeast and until 1985 did run along a natural drainage course to the Souris River. Recently the effluent drainage system was altered so that it essentially follows No. 47 highway to the river just below the confluence with Long Creek. The lagoon has been generally operated on a twice annual discharge - spring and fall - in accordance with normal Saskatchewan lagoon operating principles.

The Estevan generating station, located immediately southeast of the city, utilizes the Souris River for intake water and for cooling purposes. A small dam is constructed downstream of the generating station, which maintains channel water volumes for recirculation purposes. The return water is discharged to an old oxbow system south of the river channel. Return cooling water flows to the west and returns to the river upstream of the station. Once-through ash lagoons are also provided with discharge downstream of the station. The flows are relatively low compared to normal river flows. Site drainage would also enter the river.

Based on available information, most of the potential major point sources and impacts on the river's water quality are located in the upper portion (near the city of Estevan) of this reach.

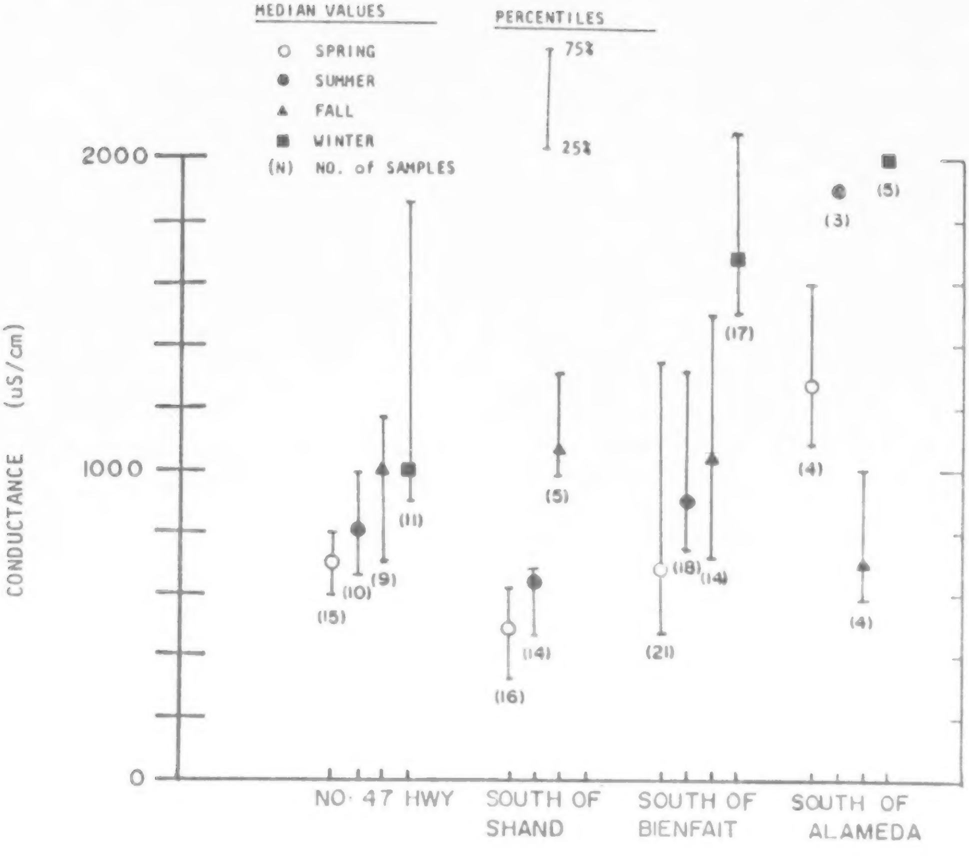
.2 Water Quality Observations

The preponderance of available water quality data is located in the upper portion of this reach - No. 47 highway and south of Bienfait (near Roche Percee) and therefore water quality observations throughout the entire reach are rather limited. The following comments are provided for major parameter groups:

a) Dissolved Salts

- For the 2 major sampling sites, conductance tends to demonstrate the typical seasonal characteristics, i.e. lower spring values during runoff with increasing concentrations as flows recede through the summer and winter period. As noted by Figure 2.18, median spring conductances are in the order of 800 to 850 uS/cm with increases in the summer to 900 to 950 uS/cm. Fall and winter values in excess of 1000 uS/L and up to the median value of 1670 (south of Bienfait) have been experienced. Limited observations south of Alameda, towards the downstream portion of this reach, demonstrate considerable variability in median conductance values with the seasons. It is expected that this is a reflection of the sampling frequency. Considering equivalent time monitoring for the sites from south of Bienfait through to south of Alameda, considerable variations are encountered.

- Chloride data generally tended to be similar to that observed for conductance although the relative variations were more apparent on a seasonal basis. Median values range from less than 30 mg/L in the spring to 40 to 50 mg/L during the winter season. This is illustrated on Figure 2.19.



SOURIS RIVER STATIONS (DOWNSTREAM) →

FIG. 2.18

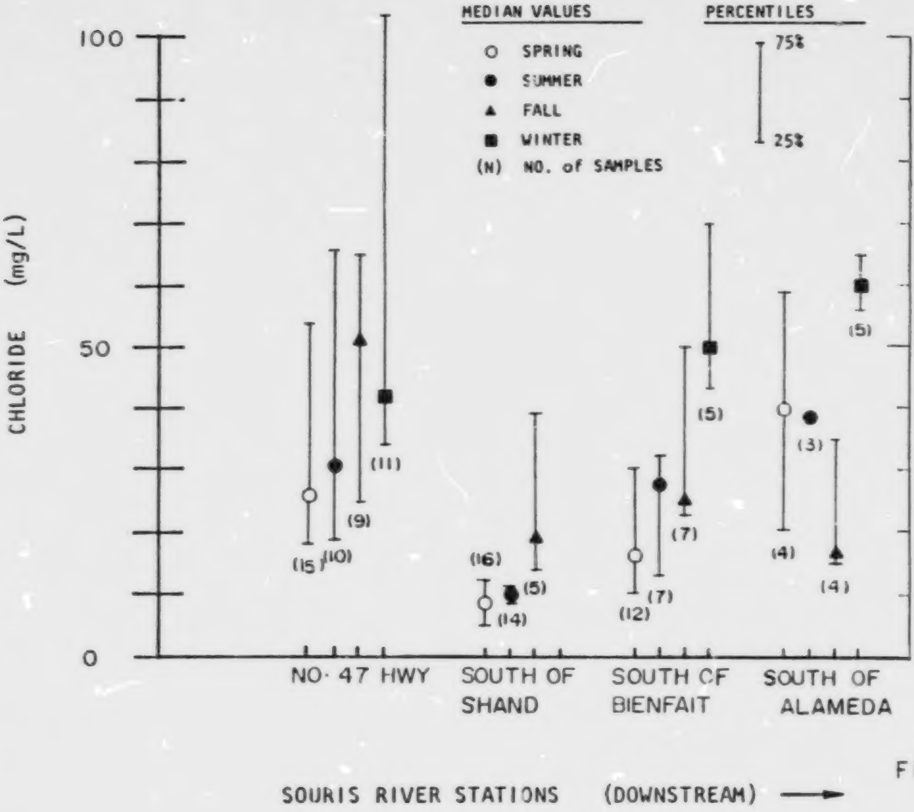


FIG. 2.19

- Major ion data for this portion of the reach is rather scanty. Based on the data available, sodium and sulphate are the predominant cations and anions respectively during summer and fall while calcium and bicarbonate predominate in the spring. SAR values range from 1 to 5 in the spring to fall periods. The substantial variations in sodium are shown by Figure 2.20.

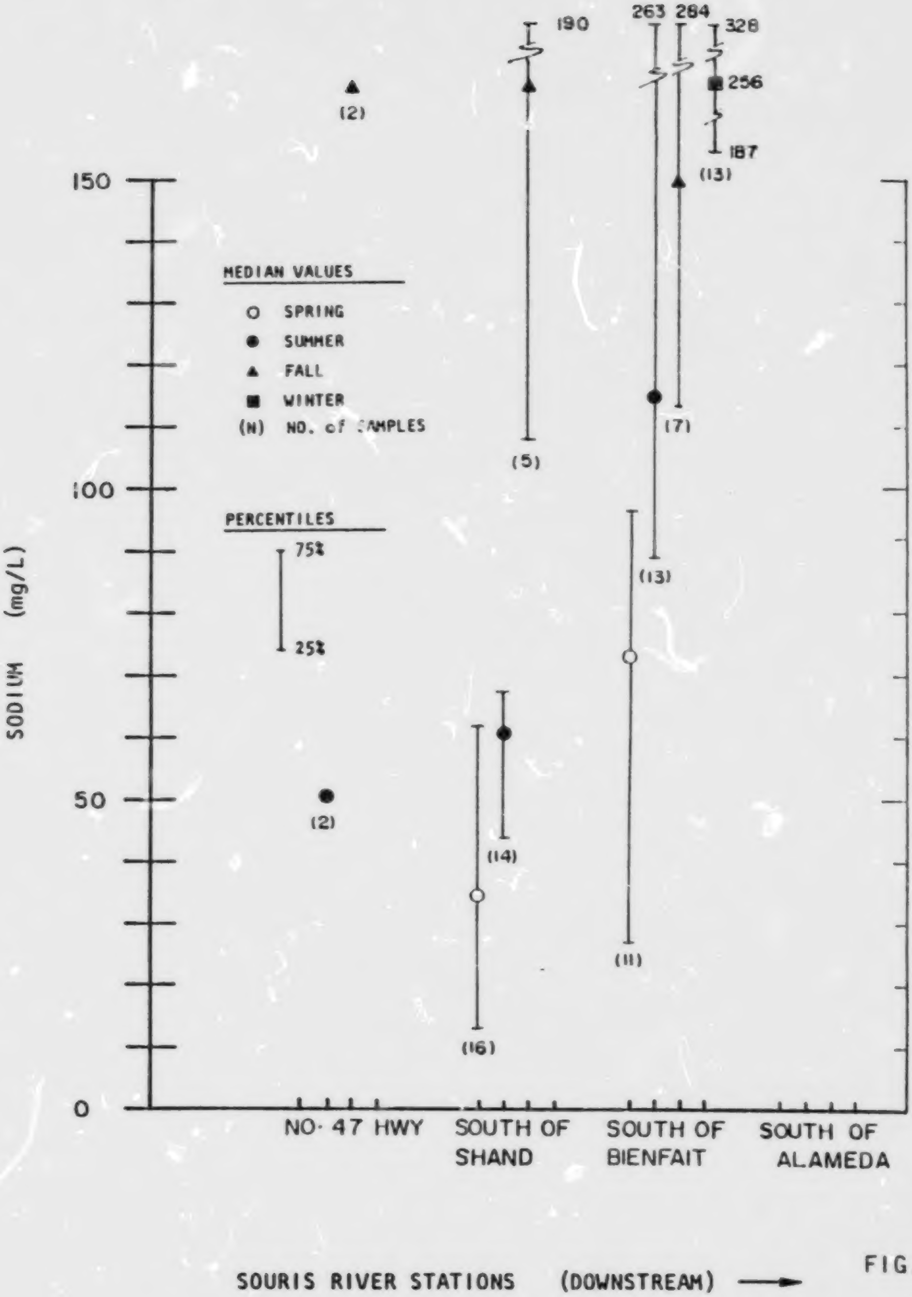

190
263
284
328
256
187
(2)
(13)
(5)
(7)
(13)
(2)
(14)
(16)
(11)
150
100
50
0
SODIUM (mg/L)
MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
NO· 47 HWY
SOUTH OF SHAND
SOUTH OF BIENFAIT
SOUTH OF ALAMEDA
SOURIS RIVER STATIONS (DOWNSTREAM) →

FIG. 2.20

b) Nutrients

As shown by Figure 2.21, the total phosphorus concentrations tended to be relatively consistent within the reach from No. 47 highway to Alameda. Slightly elevated incidents occur during the spring, summer, and winter periods south of Shand over that observed at No. 47 highway. Some of this may be due in part to the sewage effluent and urban runoff from the city of Estevan. The values vary seasonally. No consistent patterns were observed among seasonal values. Typical phosphorus levels in the river on a median basis would be expected to be in the 0.1 to 0.2 mg/L range.

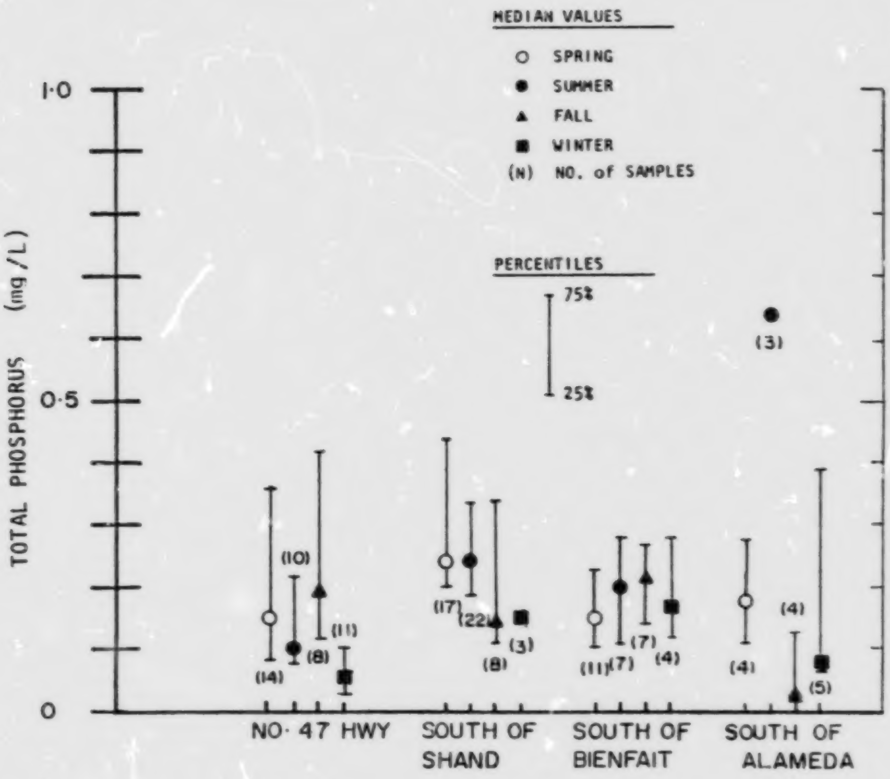


FIG. 2.21

. Nitrogen, as measured by total kjeldahl nitrogen tended to show greater variability of the 25th and 75th percentiles than did phosphorus.(Figure 2.22) Seasonal patterns were not readily apparent at any of the stations. Similarly, trends along the length of the reach are not particularly evident. Typical spring and summer values could range from 1.0 to 1.8 mg/L. Spring values, on a median basis, have a narrower window of approximately 1.4 to 1.8 mg/L. Fall concentrations were within the same ranges as for the summer. During the wintertime, no substantive differences were apparent. Ammonia nitrogen data did show seasonal effects. High winter median concentration of 0.47 to 1.22 mg/L were observed in the reach while summer and fall median values were in the 0.05 to 0.24 mg/L range.

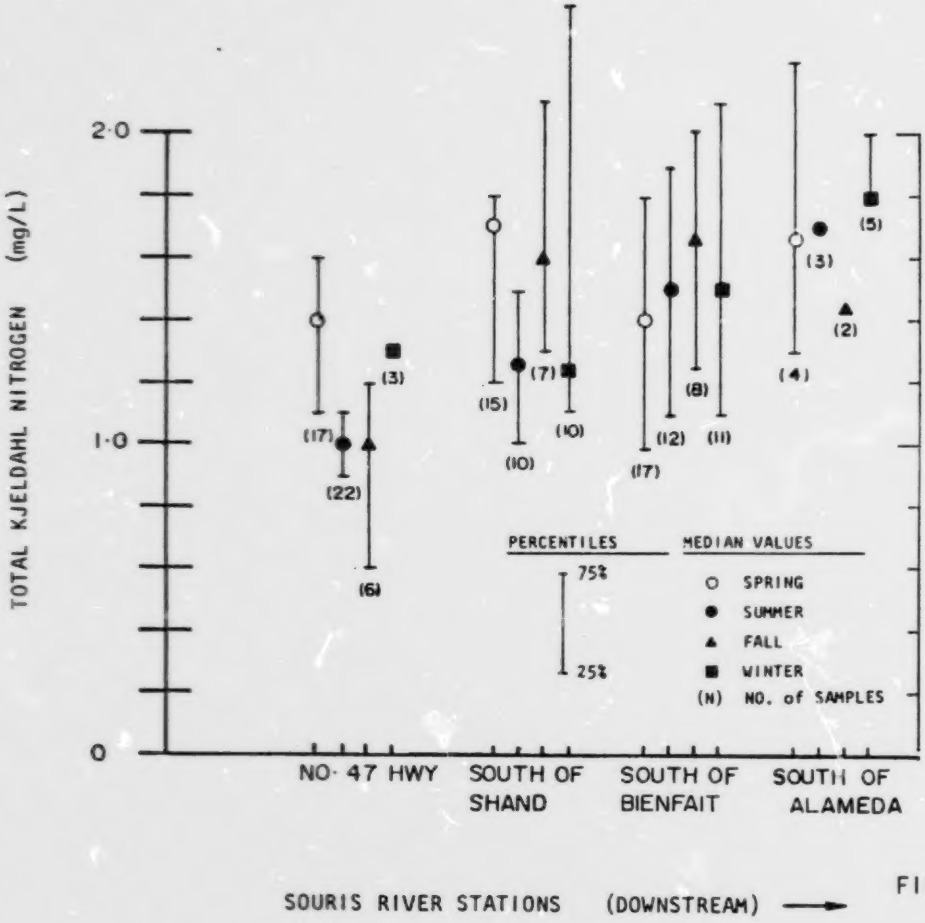


FIG. 2.22

c) Dissolved Oxygen

- As shown on Figure 2.23, dissolved oxygen data for this reach of the river indicates substantial variability both seasonally and in terms of ranges within the season. Typical spring data were in the order of 7 to 10 mg/L. However, summer data tended to be depressed at 8 to 9 mg/L, while the fall data showed higher levels perhaps as a result of late season photosynthesis. A number of instances (5 out of 26 at South of Bienfait) have been observed where oxygen levels were less than 5 mg/L. While most occur during the winter, low summer and fall values were recorded. In some cases, wintertime values were essentially negligible indicating anoxic conditions. A comparison of same day measurements at south of Bienfait and at No. 9 highway indicated consistently higher concentrations at the downstream site.

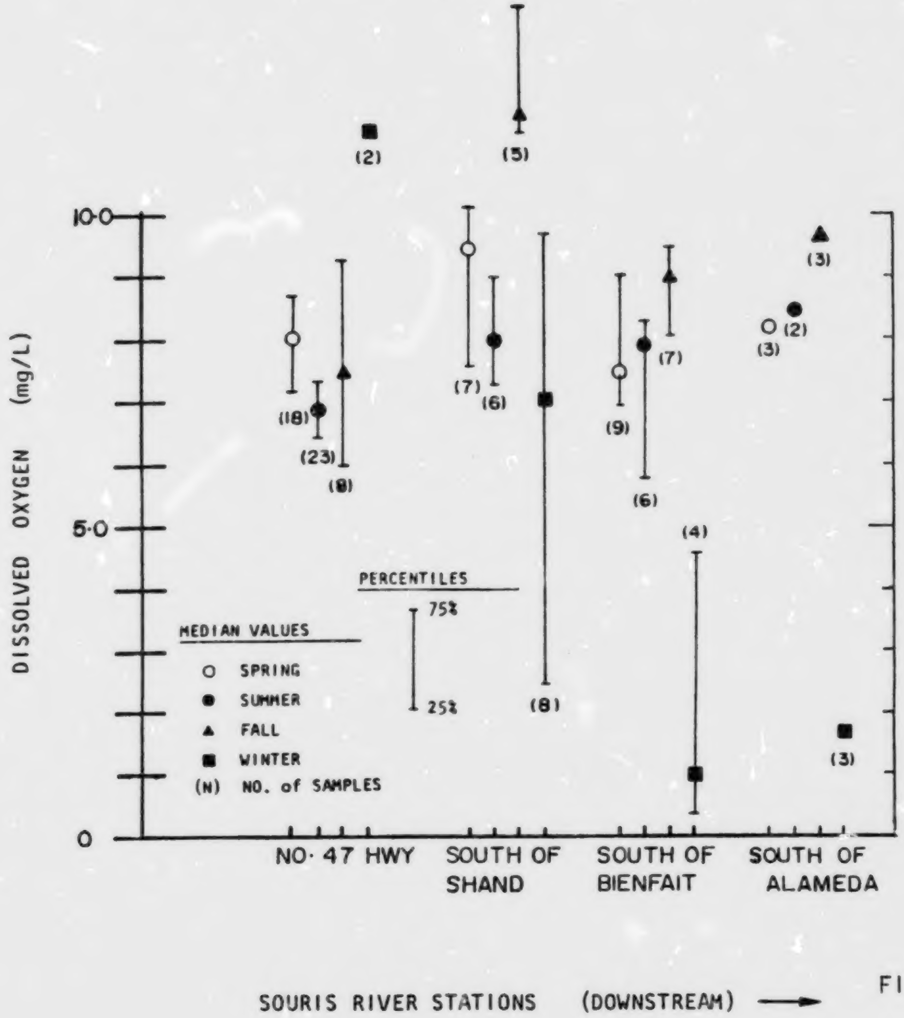


FIG. 2.23

d) Heavy Metals/Trace Substances

- Available data for the stations within this reach of the river are summarized on Table 2.8. No significant downstream trends could be discerned with any of the measurements--especially since the frequency of samples in the time period of sampling varied for some of the parameters. For many of the variables, reported values were frequently less than detection limits. Boron demonstrated some variability with maximums 1 to 2 mg/L reported. Of the 15 summer and fall data points, 10 had levels in excess of 0.5 mg/L but only 3 late fall samples exceeded 1.0 mg/L. Winter samples had the highest concentrations.

e) Biocides and Organochlorine Compounds

- Biocides and organochlorine compounds have essentially been limited to that gathered during the Souris River Basin Study. As noted from Table 2.9, the only detections have been for 2,4-D, lindane, and alpha-BHC. Lindane and alpha-BHC have been detected in very trace amounts. Similarly 2,4-D has been measured in concentrations up to 0.04 ug/L.

f) Bacteriology

- Counts of total coliforms have been erratic in this reach of the river. Median values have normally been below 2000 organisms per 100 mL but data are limited. In the upper part of the reach, data suggest a higher incidence of coliform detections, possibly due to the impact of Estevan sewage effluent discharges and/or urban runoff.

- Fecal coliform data are rather limited with median values detected during the spring through fall period (typically below 400 fecal coliforms per 100 mL).

- Fecal streptococci measurements have also been limited. Detections have been observed during the spring through fall season on the Souris River near Bienfait.

g) Miscellaneous

- Turbidity and colour measurements have also been variable in this reach of the river. There is an apparent susceptibility of the water to colour increases. Ranges of seasonal medians have been from 40 to 60 units.

TABLE 2.8 - HEAVY METALS/TRACE SUBSTANCES

EXISTING QUALITY SUMMARY

Long Creek to Moose Mountain Creek

Parameter	Form	Station	Data Base						Range (mg/L unless noted)	Comments
			Period	Samples	Seasonal Distr. Sp	Su	F	W		
Al	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	L0.10 - 1.6	1 @ L0.10
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	L0.1 - 1.1	1 @ L0.1
As	T	S006	Dec 7/81 to Nov 22/82	6	1	1	1	3	3.0 - 7.0 (ug/L)	
	D	S104	Apr 29/74	1	1	0	0	0	2.4 (ug/L)	
	D	S116	Jul 28/75 to Aug 30/76	6	0	2	3	1	3 - 6.5 (ug/L)	
	D	S008	Apr 29/74	1	1	0	0	0	2.1 (ug/L)	
	D	S111	Jun 5/78 to Mar 5/79	8	1	2	2	3	2.5 - 8.4 (ug/L)	
Ba	E	S104	Aug 24/79 to Apr 29/74	3	1	1	1	0	L0.1 - 0.1	2 @ L0.1
	E	S008	Nov 7/73 to Apr 29/74	3	1	0	1	1	L0.1 - 0.2	1 @ L0.1
Be	E	S116	July 28/75 to Aug 30/76	5	0	2	2	1	L0.01	
B	D	S006	May 7/80 to Nov 22/82	11	2	4	2	3	0.09 - 2.2	Lowest in Sp. Highest in W.
	D	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	0.12 - 0.27	
	D	S116	Jan 29/76 to Aug 30/76	2	0	1	0	1	0.25 - 0.67	
	D	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	0.16 - 2.00	Highest in F.
	E	S111	Jun 5/78 to Mar 5/79	8	1	2	2	3	0.36 - 1.04	Highest in W.
Cd	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	L0.001 - 0.009	2 @ L0.001
	E	S116	Jun 3/75 to Aug 30/76	7	2	2	2	1	L0.001 - 0.002	3 @ L0.001
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	L0.001 - 0.011	3 @ L0.001
Cr	E	S104	Aug 24/73 to Nov 8/73	2	1	1	0	0	L0.010	
	E	S116	Jun 3/75 to Aug 30/76	7	2	2	2	1	L0.015	
	E	S008	Aug 24/73 to Jan 15/74	3	0	1	1	1	L0.010	
Co	E	S104	Aug 24/73 to Nov 8/73	2	1	1	0	0	L0.001	
	E	S116	Jun 3/75 to Aug 30/76	6	1	2	2	1	L0.002 - 0.004	4 @ L0.002
	E	S008	Aug 24/73 to Jan 15/74	3	0	1	1	1	L0.001 - 0.004	1 @ L0.001 Highest in W.
Cu	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	0.001 - 0.005	
	E	S116	Jun 3/75 to Aug 30/76	7	2	2	2	1	0.006 - 0.014	
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	0.001 - 0.003	

TABLE 2.8 (Cont'd)

Parameter	Form	Station	Data Base						Range (mg/L unless noted)	Comments
			Period	Samples	Seasonal Distr.					
					Sp	Su	F	W		
F	D	S104	Jan 11/70 to Apr 29/74	13	5	3	2	3	0.08 - 0.60	
	D	S008	Jul 02/69 to Jun 5/75	34	8	9	5	12	L0.05 - 0.62	1 @ L0.05
	D	S116	Apr 23/75 to Oct 13/76	36	16	14	5	1	0.05 - 0.26	
	D	S111	Jun 05/78 to Mar 05/79	8	1	2	2	3	0.16 - 0.43	
Fe	T	S006	Jul 30/74 to Mar 10/82	3	1	1	0	1	0.2 - 0.4	Highest in W.
	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	0.13 - 1.90	Highest in Sp.
	E	S116	Jun 5/75 to Aug 30/76	6	1	2	2	1	0.23 - 2.2	Highest in Sp.
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	0.52 - 1.8	Lowest in F.
Pb	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	L0.001 - 0.005	2 @ L0.001
	E	S116	Jun 3/75 to Aug 20/76	7	2	2	2	1	L0.004 - 0.004	6 @ L0.004
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	L0.001 - 0.005	2 @ L0.001
Mn	T	S006	Jul 30/74 to May 7/80	2	1	1	0	0	L0.01	
	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	0.03 - 0.07	
	D	S104	Apr 6/72 to Mar 22/73	2	2	0	0	0	L0.01	
	D	S116	Jun 3/75 to Jul 28/75	2	1	1	0	0	0.05 - 0.15	
	E	S116	Jun 5/75 to Aug 30/76	6	1	2	2	1	0.05 - 0.14	
	D	S008	Apr 24/72 to Mar 3/73	2	2	0	0	0	L0.01	
	E	S008	Mar 3/73 to Apr 29/74	4	1	1	1	1	0.04 - 1.49	Highest in W.
Hg	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	L0.05 - 0.07 (ug/L)	1 @ L0.05
	E	S116	Jun 5/75 to Oct 21/75	4	1	1	2	0	L0.05 (ug/L)	
	E	S008	Aug 24/73 to Jan 15/74	3	2	0	0	1	L0.05 (ug/L)	
	E	S111	Jun 5/78 to Mar 5/79	8	1	2	2	3	L0.02 - 0.04 (ug/L)	5 @ L0.02
Mo	E	S104	Aug 24/73 Nov 8/73	2	0	1	1	0	L0.05	
	E	S008	Aug 24/73 to Apr 29/74	3	0	1	1	1	L0.05 - 0.08	2 @ L0.05
Ni	E	S104	Aug 24/73 to Nov 8/73	2	0	1	1	0	0.006 0 0.029	
	E	S116	Jun 3/75	1	1	0	0	0	0.018	
	E	S008	Aug 24/73 to Jan 15/74	3	0	1	1	1	0.005 - 0.47	

TABLE 2.8 (Cont'd)

Parameter	Form	Station	Data Base Period	Samples	Seasonal Distr. Sp	Su	F	W	Range (mg/L unless noted)	Comments
Se	D	S104	Apr 29/74	1	1	0	0	0	0.0005	
	E	S116	Jul 28/75 to Aug 30/76	6	0	2	3	1	0.0008 - 0.0018	
	E	S008	Apr 29/74	1	1	0	0	0	0.0005	
	D	S111	Jun 5/78 to Mar 5/79	8	1	2	2	3	0.0009 - 0.0066	
Ag	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	L0.01	
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	L0.01	
Sr	E	S104	Aug 24/73 to Nov 3/73	2	0	1	1	0	0.24 - 0.36	
	E	S008	Aug 24/73 to Jan 15/74	3	0	1	1	1	0.86 - 1.38	
V	E	S116	Jun 3/75 to Aug 30/76	7	2	2	2	1	L0.001 - 0.009	1 @ L0.001
Zn	E	S104	Aug 24/73 to Apr 29/74	3	1	1	1	0	0.002 - 0.023	1 @ L0.01
	E	S116	Jun 3/75 to Aug 30/76	7	2	2	2	1	L0.001 - 0.008	3 @ L0.001
	E	S008	Aug 24/73 to Apr 29/74	4	1	1	1	1	L0.01 - 0.038	1 @ L0.01

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

TABLE 2.9

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Long Creek to Moose Mountain Creek (Near Shand)

	Data Base							
			Seasonal Distr.					
Parameter	Period	Samples	Sp	Su	F	W	Range (ug/L unless noted)	Comments
2,4-D	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.004 - 0.04	1 @ L0.004
2,4-DB	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.009	5 @ L0.009
2,4-DP	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.004	5 @ L0.004
2,4,5-T	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.002	5 @ L0.002
MCPA	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.02	5 @ L0.02
Aldrin	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.001	5 @ L0.001
Alpha-BHC	Oct 16/75 to Jan 29/76	3	0	0	2	1	0.003 - 0.009	-highest value in fall.
Gamma-BHC (lindane)	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.001 - 0.004	2 @ L0.001 -highest value in spring
Dieldrin	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.002	5 @ L0.002
P,P-DDT	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.004	5 @ L0.004
Aroclor 1248 (PCB's)	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.024	5 @ L0.024
Aroclor 1254 (PCB's)	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.032	5 @ L0.032
Aroclor 1260 (PCB's)	Jun 05/75 to Jan 29/76	5	1	1	2	1	L0.055	5 @ L0.055

Note: Aroclor (PCB) data for stations near Estevan (S104) and south of Bienfait (S008) consisted of 2 and 3 sampling dates, respectively. These values were also all below detection limits.

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

- Turbidity has tended to be higher during high flow periods. Median values of 73 JTU have been recorded.

h) Aquatic Biology

- Examination of algae in this reach of the river is limited to two years of observations for a single station south of Shand. (Souris River Basin Study 1978) Phytoplankton populations consist predominantly of species of green algae and diatoms. The two groups tended to alternate throughout the spring, summer, and early fall with respect to dominance and diversity. Pigmented flagellates (Euglenophyta) were found to be present in low numbers through the spring and summer and dinoflagellates (Pyrrhophyta) were noted to appear in late summer and fall. Blue-green algae had been observed in the summer and fall but never in high numbers and probably not represented by bloom forming species. Based on the available data, the phytoplankton populations are probably low but the number of species anticipated to be high. No volumetric data were available.

- Chlorophyll$_a$ measurements have been obtained on a limited basis. Summer and spring values have been highest at south of Bienfait and at No. 9 highway respectively. During the summer periods, median values at these two sites were 11 and 7 mg/m^3.

- Zooplankton populations at the station south of Shand were found to be composed almost exclusively of Cladocera (water fleas) and Copepoda and these tended to fluctuate greatly throughout the open water months.(Souris River Basin Study 1978) The findings also indicated low numbers of organisms, which were suggested could be due to low water levels as well as a lack of protective aquatic vascular plant communities. With the low numbers and species numbers, the diversity index range from 0.5 to 1.0.

- Populations of benthic invertebrates tended to show seasonal and annual fluctuations based on observations during the Souris River Basin Study (1978). The oligochaetes (aquatic earthworms), dipteran larvae (2 winged flies), and Gastropoda (snails) showed yearly variations, i.e. substantial reduction or absence from one year to the next, whereas members of the Ephemeroptera (mayflies), Tricnoptera (caddis flies), and Pelecypoda (clams) maintained presence over both years of examination. The diversity indices averaged 0.3 reflective of a good variety of bottom dwellers in this reach. The presence of more pollution sensitive organisms suggests fairly good water quality in this reach.

- Aquatic vascular plants were not observed at the station south of Shand during the Souris River Basin Study (1978). It is possible that the absence of the vegetation is a reflection on the physical configuration of the river and the potential of high erosion which yields a poor habitat for rooted vegetation.

.3 Comments

Like the reach upstream of Estevan, the water quality tends to be quite variable, particularly on a seasonal basis, for many of the parameters. This would relate not only to climatic differences but also to stream flow. Although data are limited in the downstream portion of this reach and nonexistent near the confluence with Moose Mountain Creek, water quality during the summer and spring period often tends to be superior to that observed during other times of the year. Major ions demonstrate typical seasonal variations with increases from the spring through to the winter period. Interestingly, the predominant major ions also change with the season and the water converts from a calcium bicarbonate dominance in the spring to a sodium and sulphate composition during late summer and fall.

Based on the concentrations of phosphorus and nitrogen, the waters would tend to be sufficiently fertile for the growth of aquatic vegetation. Phosphorus is quite variable, while total kjeldahl nitrogen appears to be more consistent over the seasons. Observations of biological growths and organisms within the reach have essentially been limited to that carried out during the Souris River basin study and thus may not reflect current conditions. On the basis of that investigation, the waters supported typical growths of algae and other organisms but not in nuisance quantities. Dissolved oxygen has been variable and the organic nature of the water and/or the sediments, have lead to significant oxygen depletions and variations. Based on a few observations, there appears to be changes in dissolved oxygen and in levels of conductance (dissolved salts) within the reach. The water has been subject to high turbidity and colour.

Water quality within the reach, relative to corresponding parameter values contained in guidelines and objectives are summarized in Table 2.10. It is noted that for many parameters, such as nitrogen, phosphorus, and dissolved oxygen the concentrations have exceeded guideline or objective recommendations. However, for the uses within the reach, it is suspected that the water quality has not adversely affected these applications. Major concerns could relate to nitrogen in terms of use at the Estevan generating station, bacteriological levels for market garden or recreational purposes and oxygen and/or ammonia levels with respect to fish propagation. The influence of the City of Estevan from its urban runoff or treated sewage discharges is not well documented. The ability to control discharges to prescribed release periods probably has helped minimized receiving water quality problems.

2.3 Moose Mountain Creek

.1 General Factors/Uses

With headwaters immediately west of the town of Montmartre, Moose Mountain Creek is the major tributary, geographically, to the Souris River in Saskatchewan. The creek, and its rather short length tributaries, traverses agricultural lands and skirts Moose Mountain Provincial Park prior to entry into the Souris River. The creek has some significant reservoirs in its upper reaches including Moose Mountain Lake, and has a number of slough-like areas, particularly in the upper portion of the tributary. Licensed

TABLE 2.10

WATER QUALITY OBJECTIVES AND GUIDELINES

SUMMARY COMPARISONS

LONG CREEK TO MOOSE MOUNTAIN CREEK

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Calcium	--	1000 livestock L200 cooling water	35.4 - 73.5[4]	Values tend to be lower in sp; higher in w.
	(Total Hardness - 800 MDW)		(Total Hardness as $CaCO_3$ - 200 - 334[4])	
Magnesium	200 - MDW	--	13.8 - 39.7[4]	Values tend to be lower in sp; higher in w.
Sodium	300 - MDW	Depends on crop and soil type for irrigation	34.3 - 228[4]	Values tend to be lower in sp; higher in w. @ near Estevan 1/34 samples G300, @ south of Bienfait, 8/42 samples G300.
-% of cations	30 - 75	--	--	@ south of Shand, range is 29 - 60%, @ south of Bienfait, value is 24%.
-SAR	--	Restriction for irrigation: L3 none 3 - 9 slight - moderate G9 severe	--	@ south of Shand, range is 0.90 - 4.82, @ south of Bienfait, value is 0.90.
Chloride	250 - MDW	250 drinking water 100 - 700 irrigation L600 cooling water	8.4 - 107[4]	Values tend to be lower in sp; higher in w.
Bicarbonate	--	L600 cooling water	--	@ South of Bienfait, 8/40 samples G600.
	(Total Alkalinity 500 as $CaCO_3$ - MDW)		(Total Alkalinity as $CaCO_3$ - 126 - 661[4])	@ south of Bienfait, 12/70 samples G500 Total Alkalinity, @ south of Alameda, 7/16 samples G500 Total Alkalinity.
Sulphate	500 MDW	1000 livestock L680 cooling water	65 - 330[4]	--
TDS (Sum of ions)	1500 MDW	500 drinking water 500 - 3500 irrigation	727 - 1079[4]	@ #47 Hwy, 3/4 samples G500 @ below Estevan, 4/4 samples G500; 1/4 samples G1000, @ south of Bienfait, 2/2 samples G500.
TKN	1.0 (total inorganic and organic N)	10.0 nitrate } drinking w 1.0 nitrite } 100 NO_2 + NO_3 } livestock 10 nitrite } 0.06 nitrite - aquatic life	1.0 - 6.25[4]	@ #47 Hwy, 34/42 samples G1.0, @ below Estevan, 6/7 samples G1.0, @ near Estevan, 3/3 samples G1.0, @ south of Shand 27/48 samples G1.0, @ south of Bienfait, 38/48 samples G1.0, @ south of Alameda, 14/14 samples G1.0.
Ammonia, Total	--	Depends on temp. and pH	0.05 - 1.22[4]	Toxic component for aquatic life is un-ionized ammonia; this amount was calculated and found not to exceed 0.02 mg/L.
Phosphorus, Total	0.05 as P	--	0.02 - 0.75[4]	@ #47 Hwy, 32/43 samples G0.05, @ below Estevan, 5/7 samples G0.05, @ south of Shand 50/50 samples G0.05, @ south Bienfait, 25/29 samples G0.05 @ east of Roche Percee, 8/8 samples G0.05, @ south of Alameda, 12/16 samples G0.05.

TABLE 2.10 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Oxygen, Dissolved	5.0 min at any time	5.0 - 6.0 warm water 6.5 - 9.5 cold water aquatic biota	1 - 11.6[4]	@ #47 Hwy, 4/26 samples L5.0, @ south of Shand, 1/51 samples L5.0, @ south of Bienfait, 4/17 samples L5.0, @ east of Roche Percee, 1/8 samples L5.0, @ south of Alameda, 4/21 samples L5.0.
Aluminum	--	0.1 if pH ≥6.5 $[Ca^{2+}]$ ≥ 4.0 mg/L & DOC ≥ 2.0 mg/L aquatic life 5.0 - 20.0 irrigation (depends on soil) 5.0 livestock	L0.1 - 1.6	@ south of Bienfait, 3/4 samples G0.1.
Arsenic	0.01	0.05 drinking water and aquatic life 0.1 - 2.0 irrigation (depends on soil) 0.5 livestock (5.0 when not added to feed)	0.0021 - 0.0084	--
Barium	1.0	1.0 drinking water	L0.1 - 0.2	--
Beryllium	--	0.1 - 0.5 irrigation (depends on soil) 0.1 livestock	L0.01	--
Boron	0.5	5.0 drinking water 0.5 - 6.0 irrigation (depends on crop) 5.0 livestock	0.09 - 2.2	@ south of Shand, 1/2 samples G0.5, @ south of Bienfait, 3/4 samples G0.5, @ #47 Hwy, 9/11 samples G0.5.
Cadmium	0.01 0.005 MDW	0.005 drinking water 0.2 - 1.8 aquatic life (depends on hardness) 0.01 irrigation 0.02 livestock	L0.001 - 0.011	@ south of Bienfait, 1/4 samples G0.005.
Chromium	0.05	0.05 drinking water 0.02 fish; 2.0 aquatic life; 0.1 irrigation 1.0 livestock	L0.010 - L0.015	--
Cobalt		0.05 - 5.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.004	--
Copper	0.02	1.0 drinking water 2 - 4 aquatic life (depends on hardness) 0.2 - 1.0 irrigation (depends on crop) 0.5 - 5.0 livestock (depends on animal)	0.001 - 0.014	--
Fluoride	1.5 1.5 MDW	1.5 drinking water 1.0 - 15.0 irrigation (depends on soil) 2.0 livestock (1.0 if feed contains fluoride)	L0.05 - 0.62	--
Iron	0.3 0.3 MDW	0.3 drinking water 0.3 aquatic life 5.0 - 20.0 irrigation (depends on soil)	0.13 - 2.2	@ south of Shand, 5/6 samples G0.3, @ south of Bienfait, 4/4 samples G0.3
Lead	0.05	0.05 drinking water 1 - 7 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.005	--

TABLE 2.10 (Cont'd)

Parameter	Water Quality Objectives/Guidelines		Observed Ranges[3] (mg/L unless noted)	Comments
	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)		
Manganese	0.05	0.05 drinking water 0.2 - 10.0 irrigation (depends on soil)	L0.01 - 1.49	@ south of Shand, 6/8 samples G0.05, @ south of Bienfait, 3/6 samples G0.05.
Mercury	0.1 ug/L 1 ug/L MDW	1 ug/L drinking water 0.1 ug/L aquatic life 3 ug/L livestock	L0.02 - 0.07 ug/L.	—
Molybdenum		0.01 - 0.05 irrigation (depends on soil) 0.5 livestock	L0.05 - 0.08	@ south of Bienfait, 1/3 samples G0.05.
Nickel		25 - 150 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 1.0 livestock	0.005 - 0.47	--
Selenium	0.01	0.01 drinking water 0.001 aquatic life 0.02 irrigation 0.05 livestock	0.0005 - 0.0066	--
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.01	Note: detection limits greater than guidelines for aquatic life.
Vanadium	--	0.1 - 1.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.009	--
Zinc	0.05	5.0 drinking water 0.03 aquatic life 1.0 irrigation, if soil pH L6.5; 5.0, if soil pH G6.5	L0.001 - 0.038	@ south of Bienfait, 1/4 samples G0.03.
Aldrin & Dieldrin	0.7 ug/L - MDW	0.7 ug/L drinking water 0.004 ug/L (dieldrin) aquatic life	L0.001 aldrin L0.002 dieldrin ug/L	--
2,4-D	0.1 - MDW	0.1 drinking water 4.0 ug/L aquatic life (phenoxy herbicides)	L0.004 - 0.04 ug/L	--
DDT	0.03 - MDW	0.03 drinking water 0.001 ug/L aquatic life	P,P - L0.004 ug/L	--
Lindane (Gamma-BHC)	4 ug/L - MDW	4 ug/L drinking water	L0.001 - 0.004 ug/L	--
Coliforms, Total	L5,000/100 mL for potable supply or recreation (not direct contact) for ≥ 90% of the samples (not ≥ 5 samples/30-d period) -depends on type and degree of pollution, local conditions in watershed. L1000/100 mL geom. mean of 5 samples for direct contact recreation or vegetable crop irrigation for ≤ 20% of the samples in one month, or ≤ 2400/100 mL/day.	1000/100 mL irrigation high quality -livestock	115-13,190/100 mL[4](MF) 90 - 1500/100 mL[4](MPN) (provincial data)	@ south of Shand, 1/46 samples G5000/100 mL, @ south of Shand, 3/46 samples G2400/100 mL, @ south of Shand 5/46 samples G1000/100 mL, @ south of Bienfait, 1/21 samples G5000/100 mL, @ south of Bienfait, 2/21 samples G2400/100 mL, @ south of Bienfait 5/21 samples G1000/100 mL.

TABLE 2.10 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Coliforms, Fecal	L1000/100 mL (see above) L200/100 mL (see above)	—	13 - 360/100 mL‡ (MF) L23 - 760/100 mL‡ (MPN) (provincial data)	@ south of Shand, 2/47 samples G1000/100 mL, @ south of Shand 6/47 samples G200/100 mL, @ south of Bienfait, 9/28 samples G200/100 mL.
pH	6.5 - 8.5 but not 0.5 units over background value	6.5 - 8.5 drinking water 5.0 - 8.3 cooling water	7.1 - 8.6‡(field)	@ south of Shand, 2/51 samples G8.3, @ south of Bienfait, 1/10 samples G8.3.
Colour	≤ 30 TCU increase above natural value	15 TCU drinking water	10 - 90 relative units‡	Values tend to be higher in sp and sum, lower in w.
Turbidity	≤ 25 NTU over natural turbidity	5 NTU drinking water	9.3 - 73‡ (at south of Shand)	Values tend to be higher in sp and sum, lower in w.
Temperature	≤ 3°C increase above ambient water temp	15°C drinking water No alterations of thermal stratification or turn-over dates; no exceedences of max weekly ave temp, and no exceedences of max short-term temp.	18.3 - 23°C‡ (summer)	--

Notes: Objectives/guidelines denote "less than or equal to" values unless otherwise stated.

[1] Saskatchewan Environment Water Quality Objectives, 1983 (Surface Water Quality Objectives)
Saskatchewan Environment Municipal Drinking Water Quality Objectives, June 1980 (MDW)

[2] Canadian Council of Resource and Environment Ministers - Canadian Water Quality Guidelines, March 1987

[3] Observed Ranges - ‡ signifies median ranges.

uses in the lower reach, i.e. from south of Carlyle to the mouth are rather limited to a private reservoir and an irrigator. Other uses would include domestic stock watering and wildlife and fish use. The creek could be the receptor of effluents from a number of communities but primarily on an indirect basis, i.e. through the short tributaries. Examples include Alameda, Arcola, Montmartre, Carlyle, Corning, and Kisby. Impacts are not expected to be significant. It is suspected that groundwater can also inflow into the creek under certain conditions, particularly in the lower reach.

.2 Water Quality Observations

Water quality monitoring according to the federal-provincial stations and the corresponding data banks initiates with an upper station at No. 13 highway east of Forget, 101 km above the mouth. A further station exists at No. 9 highway south of Carlyle, but the major data base is centered on the station west of Oxbow just above the confluence. Since the data from the two upstream stations are rather sparse, the site near the mouth is the only location where reasonable reviews can be made. Water quality observations for parameter groups that centre on this site follow:

a) Dissolved Salts

- As noted from Figure 2.24, median and 25th to 75th percentiles of conductance vary substantially by season. Median ranges were approximately 800, 1040, 1380, and 2830 uS/cm for the spring through winter seasons respectively. The number of data points for the fall and winter season are considerably less than that obtained in the spring. Maximum and minimum 25th and 75th values were approximately 485 uS/cm in the spring and 3460 uS/cm in the winter.
- Regression analyses of federal data indicates TDS (sum of ions) = 0.853 conductance - 9 (n=25; r=0.99).
- Major ion analyses are only available for the spring through fall period. Considering 1975 and 1976 data, predominant cations tended to be in the order of magnesium, calcium, sodium, and potassium, while bicarbonate normally exceeded sulphate as a major anion. This latter predominance tended to markedly decline towards the late or low flow part of the year. Chloride and sodium trends are shown on Figure 2.24.
- Sodium adsorption ratios, calculated from spring and summer data, ranged from 0.6 to 1.8.

b) Nutrients

- The majority of the total phosphorus data was collected during spring and summer seasons with only minimal data available for fall and winter. During the warm periods,

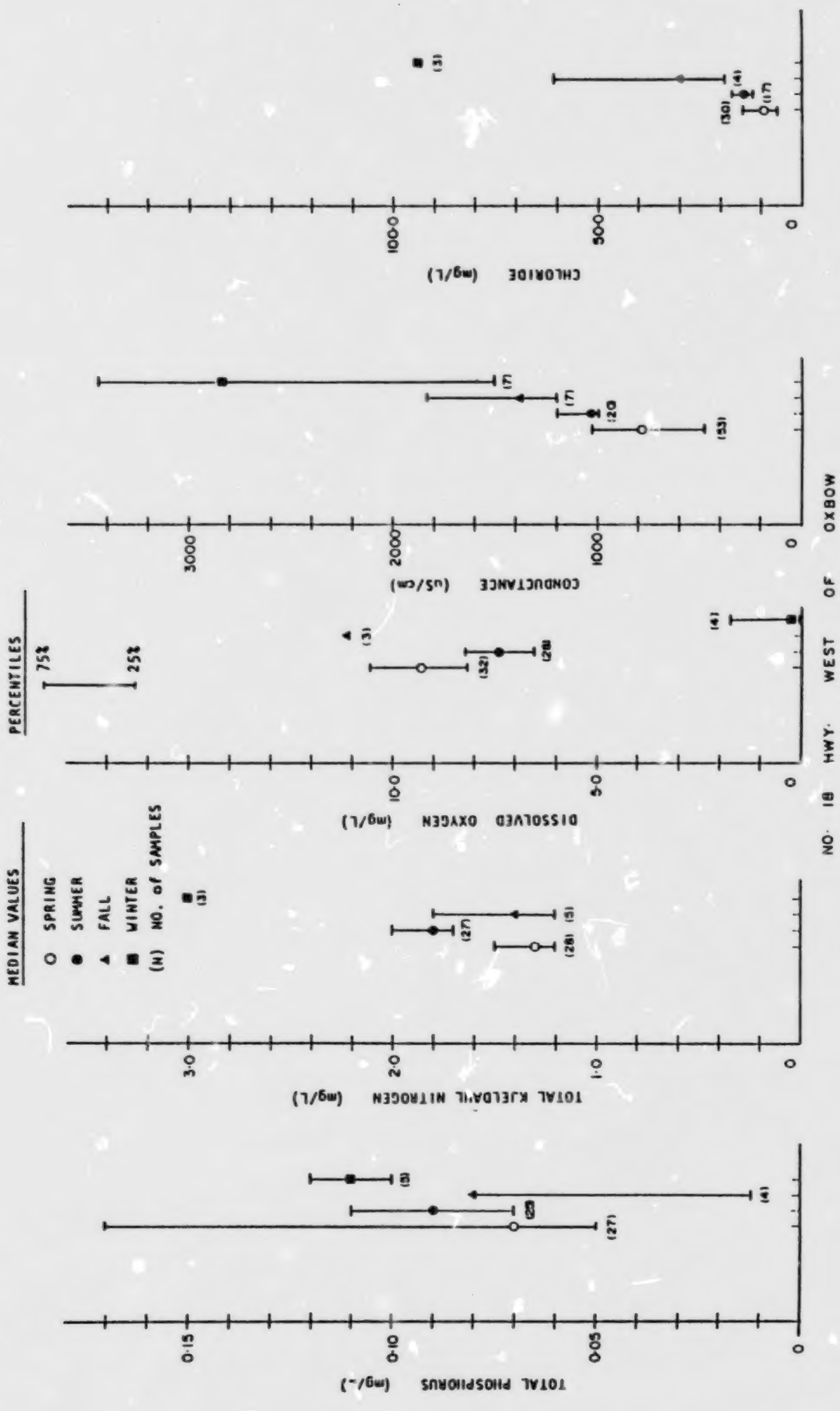

MEDIAN VALUES
○ SPRING
● SUMMER
▲ FALL
■ WINTER
(N) NO. of SAMPLES
PERCENTILES
75%
25%
TOTAL PHOSPHORUS (mg/L)
0
0.05
0.10
0.15
(27)
(28)
(4)
(3)
TOTAL KJELDAHL NITROGEN (mg/L)
0
1.0
2.0
3.0
(28)
(27)
(5)
(3)
DISSOLVED OXYGEN (mg/L)
0
5.0
10.0
(32)
(28)
(3)
(4)
CONDUCTANCE (uS/cm)
0
1000
2000
3000
(33)
(21)
(7)
(7)
CHLORIDE (mg/L)
0
50.0
100.0
(30)
(17)
(4)
(3)
NO. 18 HWY. WEST OF OXBOW

FIG. 2.24

phosphorus levels on a median basis tended to be relatively low and ranged from 0.07 to 0.09 mg/L for the spring and summer respectively. For the same period, 25th and 75th percentiles showed variations of up to 0.1 mg/L. This is shown on Figure 2.24.

. Total kjeldahl nitrogen values were also more readily available for the spring and summer periods. As noted from Figure 2.24, the variations around the median were rather minor. Median values for spring and summer were 1.3 and 1.8 mg/L respectively. Limited winter data suggest increases of approximately twofold. Based on only a few analyses for ammonia nitrogen, spring and summer median values were 0.10 mg/L or less with increases in other seasons.

c) Dissolved Oxygen

. As noted on Figure 2.24, median dissolved oxygen levels in the spring through summer periods tended to decrease (9.4 to 7.4 mg/L). The fall and winter data bases are rather small, but indicate potential high levels during the fall period and very low levels under ice cover. Based on the available data, 5 out of 62 samples had dissolved oxygen levels less than 5 mg/L. All of these occurred during the ice cover period, when flows would be very low or virtually nonexistent.

d) Heavy Metals/Trace Substances

. Available data for heavy metals and trace substances was generally limited to that gathered during the mid-1970s. The data, summarized on Table 2.11, do not indicate any significant concentrations of these constituents. For many of the potentially toxic heavy metals, concentrations were often below detection limits. Extractable iron and manganese were found to be high, particularly during the wintertime, possibly due to reducing conditions in the watercourse. Boron was generally less than 0.5 mg/L.

e) Biocides and Organochlorine Compounds

. Limited data, gathered during the Souris River Basin Study for Moose Mountain Creek near Oxbow, are limited to common herbicides, pesticides, and polychlorinated biphenyls typical of available analytical capability. Table 2.12 summarizes the existing data population and the incidents of positive detections. Of the compounds measured, only lindane, alpha-BHC, and 2,4-D were measured in

TABLE 2.11

HEAVY METALS/TRACE SUBSTANCES

EXISTING QUALITY SUMMARY

Moose Mountain Creek (Near Oxbow)

		Data Base		Seasonal Distr.					
Parameter	Form	Period	Samples	Sp	Su	F	W	Range (mg/L unless noted)	Comments
Al	E	June 7/72 to Apr 6/77	14	4	5	3	2	L0.10 - 0.22	7 @ L0.10
As	D	June 7/72 to Apr 6/77	13	6	4	2	1	0.0007 - 0.024	2 @ L0.005
Ba	E	June 7/72 to Apr 6/77	14	5	4	3	2	L0.05 - 0.3	8 @ L0.1
Be	E	July 29/75 to Apr 6/77	6	1	3	2	0	L0.01	
B	D	Nov 30/72 to Apr 6/77	11	3	3	3	2	0.11 - 0.35	
Cd	E	June 7/72 to Apr 6/77	18	6	6	4	2	L0.001 - 0.005	13 @ L0.001
Cr	E	June 7/72 to Apr 6/77	19	7	6	4	2	L0.01 - 0.015	9 @ L0.015
Co	E	June 7/72 to Apr 6/77	18	6	6	4	2	L0.001 - 0.006	5 @ L0.001
Cu	E	June 7/72 to Apr 6/77	19	7	6	4	2	L0.001 - 0.006	6 @ L0.001
CN^-	D	May 6/76 to Apr 6/77	4	2	1	1	0	L0.005	
F	D	June 7/72 to Apr 6/77	52	28	16	4	4	L0.05 - 0.98	4 @ L0.05
Fe	E	June 7/72 to Apr 6/77	15	6	4	3	2	0.10 - 9.70	Highest values in winter(1.80,9.70)
	T	July 30/74	1		1			0.4	
Pb	E	June 7/72 to Apr 6/77	19	7	6	4	2	L0.001 - 0.03	9 @ L0.004
Mn	E	June 7/72 to Apr 6/77	14	5	3	3	3	L0.01 - 3.65	2 @ L0.01 Highest values in winter(3.40,3.65)
Mn	D	Mar 13/73 to July 29/75	3	2	1	0	0	0.03 - 0.19	
	T	July 30/74	1		1			0.01	
Hg	D	June 7/72 to Apr 6/77	16	6	5	4	1	L0.05 - 0.24 (ug/L)	9 @ 0.05
Mo	E	Aug 23/73 to Aug 5/76	7	2	3	1	1	L0.05 - L0.10	5 @ L0.05* 2 @ L0.10
Ni	E	June 7/72 to Apr 6/77	15	6	4	3	2	L0.001 - 0.021	2 @ L0.001
Se	D	Apr 22/75 to Apr 6/77	7	3	2	2	0	L0.0005 - 0.0006	6 @ L0.0005
Ag	E	June 7/72 to Aug 7/74	7	2	3	1	1	L0.01	
Sr	E	June 7/72 to Apr 6/77	13	5	3	3	2	0.14 - 1.05	Highest values in winter(0.74,1.05)
V	E	Apr 24/74 to Oct 5/76	10	4	4	2	0	L0.001 - L0.05	2 @ L0.05 3 @ L0.001 1 @ L0.002 Max detection @ 0.003
Zn	E	June 7/72 to Apr 6/77	19	7	6	4	2	L0.001 - 0.013	1 @ L0.01 6 @ L0.001

* Change in detection limits due to change in analytical methodologies.

Notes:
1) L - less than
2) Sp - spring F - fall
Su - summer W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

TABLE 2.12

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Moose Mountain Creek (Near Oxbow)

Parameter	Data Base						Range	Comments
			Seasonal Distr.					
	Period	Samples	Sp	Su	F	W	(ug/L unless noted)	
2,4-D	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.004 - 0.2	2 @ L0.004
2,4-DB	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.009	
2,4-DP	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.004	
2,4,5-T	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.002	
MCPA	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.2	
Aldrin	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.001	
Alpha-BHC	Oct 20/75	1	0	0	1	0	0.007	
Gamma-BHC (Lindane)	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.001 - 0.005	2 @ L0.001
Dieldrin	Apr 24/74 to Oct 20/75	8	2	5	1	0	L0.002	
P,P-DDT	Apr 24/74 to Oct 20/75	7	1	5	1	0	L0.004	
Aroclor 1248	Aug 23/73 to Oct 20/75	11	2	6	2	1	L0.024	
Aroclor 1254	Aug 23/73 to Oct 20/75	11	2	6	2	1	L0.032	
Aroclor 1260	Aug 23/73 to Oct 20/75	11	2	6	2	1	L0.055	

Notes:
1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

concentrations above the detection limits. Maximum recorded values were 0.005 ug/L for lindane, 0.007 ug/L for alpha-BHC, and 0.2 ug/L for 2,4-D.

f) Bacteriology

- Total coliform data for Moose Mountain Creek are limited, with only 11 samples collected for the station west of Oxbow and a total of 12 samples for all the upstream stations. Median spring and summer findings were all less than 1000 organisms per 100 mL. A single fall sample west of Moose Mountain Creek had the maximum recorded value of 2300 total coliforms per 100 mL.

- Fecal coliform data are similarly limited. Median spring and summer values have ranged as high as 785 organisms per 100 mL. Summer values tended to show somewhat lower densities.

- Limited fecal streptococci information from the station west of Oxbow yielded high summer values with a median of 200 organisms per 100 mL (based on only 2 samples).

- Generally the bacteriological data are inadequate to precisely characterize this quality, although indications are that populations are not abnormally high.

g) Miscellaneous

- Limited data for the physical characteristics of turbidity and colour, indicate low open water median turbidity levels (3.5-6 JTU) and high median colour ranging from 30 to 60 units.

h) Aquatic Biology

- Available data on aquatic biology for Moose Mountain Creek is limited to that gathered through the Souris River Basin Study (1978).

- Algae or phytoplankton were found to be represented by predominantly Chlorophyta (green algae) and Bacillariophyceae (diatoms). Both groups were characterized by relatively high numbers of species and generally low numbers of organisms in spring and summer. Green algae tended to dominate. Blue-green algae and pigmented flagellates were found to be present at very low numbers during the spring and summer. The diversity index for the phytoplankton averaged 1.2.

- Limited chlorophyll data indicated median values of 10 mg/m^3 during the summertime with 90th percentiles reaching 16 mg/m^3.

- Zooplankton populations were found to be characterized by very low numbers and kinds.(Souris River Basin Study 1978) At certain times of the year throughout spring and summer, no organisms were found. Representatives of the Cladocera and Copepoda were the predominant groups inhabiting the tributary. The diversity indices for Moose Mountain Creek averaged a very low 0.3.

- Benthic invertebrates were also characterized by very low numbers and kinds resulting in an average diversity index of 0.2.(Souris River Basin Study 1978) During the period of examination, benthic organisms were found to exhibit wide fluctuations both seasonally and annually with some organisms occurring in one season or year and being reduced to totally absent the next. Leeches (Hirudinea) were not found-- possibly due to the muddy substrate. Additionally, other groups not represented were the snails (Gastropoda) and the side swimmers (Amphipoda), which normally require high dissolved oxygen requirements. Members of the Oligochaeta (aquatic earthworms), dipteran larvae (2 winged flies), Pelecypoda (clams), Ephemeroptera (mayflies), and Coleoptera (beetles) made up the benthic population of Moose Mountain Creek. Due to the variations in findings, and their current dissolved oxygen level tolerance or requirements, it is possible that a suitable substrate may be more of a limiting environmental factor for benthic invertebrates in this reach.

- The growth of macrophytes in Moose Mountain Creek has been reported as abundant with rooted macrophytes such as sedges (*Scirpus validus*), spike rushes (*Eleocharis calva*), and cattails (*Typha latifolia*) and the submerged hornwort (*Ceratophyllum demersum*) found to inhabit the shallower waters around the edge.(Souris River Basin Study 1978)

.3 Comments

Examination of water quality in Moose Mountain Creek was essentially limited, due to data availability, to near the mouth. Where data were available, seasonal flow variations for dissolved salts were readily apparent. Marked increases from spring through the wintertime were observed although the winter and fall data populations were quite low.

For many of the other parameters, most of the data were gathered during the open water periods. Phosphorus and especially nitrogen are available to support algae and other aquatic growths. However, based on observations during the Souris River basin study, the algal growths are moderate and without the prevalence of nuisance organisms. In shallow reaches emergent aquatic vegetation has been observed.

Dissolved oxygen tends to vary and, not unexpectedly, low levels have been observed under ice cover. Concentrations of other constituents have tended to be relatively low.

The available data are compared with water quality guidelines and objectives in Table 2.13. The water would be considered suitable for most uses and, since there are no identified major point sources of potential pollutants, tends to reflect typical prairie streams subject to agricultural land drainage.

2.4 Souris River - Moose Mountain Creek to the International Border

.1 General Factors/Uses

From the mouth of Moose Mountain Creek, this 64.7 km reach to the U.S. border is characterized by a well defined river channel and banks. The only urban centre adjacent to the river is the Town of Oxbow. A shallow reservoir is created at Oxbow due to a small instream dam. The river traverses agricultural lands on which there is neighbouring petroleum activity.

TABLE 2.13

WATER QUALITY OBJECTIVES AND GUIDELINES SUMMARY COMPARISONS MOOSE MOUNTAIN CREEK

Parameter	Water Quality Objectives/Guidelines		Observed Ranges[3] (mg/L unless noted)	Comments
	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)		
Calcium	--	1000 livestock L200 cooling water	53.5 - 94.3*	Values tend to be lower in sp; higher in fall.
	(Total Hardness - 800 MDW)	--	(Total Hardness as $CaCO_3$ - 75.1 - 668*)	--
Magnesium	200 - MDW	--	45 - 87*	Values tend to be lower in sp; higher in fall.
Sodium	300 - MDW	Depends on crop and soil type for irrigation	45.5 - 300*	Values tend to be lower in sp; higher in w. @ #18 Hwy, 3/57 samples G300.
-% of cations	30 - 75%	--	--	@ #18 Hwy, range is 15 - 41%.
-SAR	--	Restriction for irrigation: L3 none 3 - 9 slight - moderate G9 severe	--	@ #13 Hwy, range is 0.6 - 1.8.
Chloride	250 - MDW	250 drinking water 100 - 700 irrigation L600 cooling water	9.7 - 94*	Values tend to be lower in sp; higher in w.
Bicarbonate	--	L600 cooling water	--	Values tend to be lower in sp; higher in w. @ #18 Hwy, 4/52 samples G600.
	(Total Alkalinity 500 as $CaCO_3$ - MDW)		(Total Alkalinity as $CaCO_3$ - 302 - 736*)	@ #18 Hwy, 6/65 samples G500.
Sulphate	500 MDW	1000 livestock L680 cooling water	--	Values tend to be lower in sp. @ #18 Hwy, 1/36 samples G500.
TKN	1.0 (total inorganic and organic N)	10.0 nitrate, 1.0 nitrite } drinking w 100 $NO_3 + NO_2$, 10 nitrite } livestock 0.06 nitrite - aquatic life	1.3 - 3*	Values tend to be lower in sp and f, higher in sum and w. @ #18 Hwy, 63/63 samples G1.0.
Ammonia, Total	--	Depends on temp and pH	0.01 - 0.95*	--
Phosphorus, Total	0.05 as P	--	0.07 - 0.21*	@ #18 Hwy, 49/58 samples G0.05.
Oxygen, Dissolved	5.0 min at any time	5.0 - 6.0 warm water 6.5 - 9.5 cold water aquatic biota	0.2 - 11.1*	Winter values tend to be very low. @ #18 Hwy, 5/67 samples L5.0.
Aluminum	--	0.1 if pH 26.5 [Ca^{2+}] ≥ 4.0 mg/L & DOC ≥ 2.0 mg/L aquatic life 5.0 - 20.0 irrigation (depends on soil) 5.0 livestock	0.012 - 0.22	@ #18 Hwy, 3/14 samples G0.1.
Arsenic	0.01	0.05 drinking water and aquatic life 0.1 - 2.0 irrigation (depends on soil) 0.5 livestock (5.0 when not added to feed)	0.0007 - 0.024	@ #18 Hwy, 1/13 samples G0.01.
Barium	1.0	1.0 drinking water	L0.05 - 0.3	--
Beryllium	--	0.1 - 0.5 irrigation (depends on soil) 0.1 livestock	L0.01	--

TABLE 2.13 (Cont'd)

Parameter	Water Quality Objectives/Guidelines		Observed Ranges[3] (mg/L unless noted)	Comments
	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)		
Boron	0.5	5.0 drinking water 0.5 - 6.0 irrigation (depends on crop) 5.0 livestock	0.11 - 0.35	--
Cadmium	0.01 0.005 MDW	0.005 drinking water 0.2 - 1.8 aquatic life (depends on hardness) 0.01 irrigation 0.02 livestock	L0.001 - 0.005	--
Chromium	0.05	0.05 drinking water 0.02 fish; 2.0 aquatic life; 0.1 irrigation 1.0 livestock	L0.01 - 0.015	--
Cobalt	--	0.05 - 5.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.006	--
Copper	0.02	1.0 drinking water 2 - 4 aquatic life (depends on hardness) 0.2 - 1.0 irrigation (depends on crop) 0.5 - 5.0 livestock (depends on animal)	L0.001 - 0.006	--
Cyanide	0.01	0.2 drinking water 5.0 (free cyanide as CN) aquatic life	L0.005	--
Fluoride	1.5 1.5 MDW	1.5 drinking water 1.0 - 15.0 irrigation (depends on soil) 2.0 livestock (1.0 if feed contains fluoride)	L0.05 - 0.98	--
Iron	0.3 0.3 MDW	0.3 drinking water 0.3 aquatic life 5.0 - 20.0 irrigation (depends on soil)	0.10 - 9.70	@ #18 Hwy, 4/20 samples G0.3. Winter values tend to be in higher range.
Lead	0.05	0.05 drinking water 1 - 7 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.03	--
Manganese	0.05	0.05 drinking water 0.2 - 10.0 irrigation (depends on soil)	L0.01 - 3.65	@ #18 Hwy, 12/22 samples G0.05. Winter values tend to be in higher range.
Mercury	0.1 ug/L 1 ug/L MDW	1 ug/L drinking water 0.1 ug/L aquatic life 3 ug/L livestock	L0.05 - 0.24 ug/L.	@ #18 Hwy, 3/16 samples G0.1 ug/L.
Molybdenum	--	0.01 - 0.05 irrigation (depends on soil) 0.5 livestock	L0.05 - L0.10	--
Nickel	--	25 - 150 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.021	--
Selenium	0.01	0.01 drinking water 0.001 aquatic life 0.02 irrigation 0.05 livestock	L0.0005 - 0.0006	--
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.01	--

TABLE 2.13 (Cont'd)

Parameter	Water Quality Objectives/Guidelines		Observed Ranges[3] (mg/L unless noted)	Comments
	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)		
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.01	--
Vanadium	--	0.1 - 1.0 irrigation (depends on soil) 0.1 livestock	L0.001 - L0.05	--
Zinc	0.05	5.0 drinking water 1.0 irrigation, if soil pH L6.5; 5.0, if soil pH G6.5	L0.001 - 0.013	--
Aldrin & Dieldrin	0.7 ug/L - MDW	0.7 ug/L drinking water 0.004 ug/L (dieldrin) aquatic life	L0.001 aldrin L0.002 dieldrin ug/L	--
2,4-D	0.1 - MDW	0.1 drinking water 4.0 ug/L aquatic life (phenoxy herbicides)	L0.004-0.2 ug/L	Highest values tend to be in w. @ #18 Hwy, 2/8 samples G0.1.
DDT	0.03 - MDW	0.03 drinking water 0.001 ug/L aquatic life	P,P - L0.004 ug/L	--
Lindane (Gamma-BHC)	4 ug/L - MDW	4 ug/L drinking water	L0.001 - 0.005 ug/L	--
Coliforms, Total	L5,000/100 mL for potable supply or recreation (not @direct contact) for ≥90% of the samples (not ≥5 samples/30-d period) -depends on type and degree of pollution, local conditions in watershed. L1000/100 mL geom. mean of 5 samples for direct contact recreation or vegetable crop irrigation for ≤20% of the samples in one month, or ≤ 2400/100 mL/day.	--	40 - 930/100 mL* (MPN) 900/100 mL*(MF) (provincial data)	@ #18 Hwy, 5/52 samples G1000.
Coliforms, Fecal	L1000/100 mL (see above) L200/100 mL (see above)	--	31 - 785/100 mL* (MPN) 395/100 mL*(MF) (provincial data)	@ #18 Hwy, 2/51 samples G1000. @ #18 Hwy, 10/51 samples G200.
pH	6.5 - 8.5 but not 0.5 units over background value	6.5 - 8.5 drinking water 5.0 - 8.3 cooling water	7.5 - 8.5 (field)*	@ #18 Hwy, 14/69 samples G8.5. @ #18 Hwy, 44/69 samples G8.3.
Colour	≤30 TCU increase above natural value	15 TCU drinking water	30 - 63 relative units*	--
Turbidity	≤25 NTU over natural turbidity	5 NTU drinking water	3.5 - 32 JTU*	--
Temperature	≤3°C increase above ambient water temp.	15°C drinking water No alterations of thermal stratification or turn-over dates; no exceedences of max weekly ave temp, and no exceedences of max short-term temp.	20.5°C* (summer)	--

Notes: Objectives/guidelines denote "less than or equal to" values unless otherwise stated.

[1] Saskatchewan Environment Water Quality Objectives, 1983 (Surface Water Quality Objectives)
Saskatchewan Environment Municipal Drinking Water Quality Objectives, June 1980 (MDW)

[2] Canadian Council of Resource and Environment Ministers - Canadian Water Quality Guidelines, March 1987

[3] Observed Ranges - * signifies median ranges.

Major uses include irrigation, recreation, and fish and wildlife. The Town of Oxbow uses a groundwater supply adjacent to the river for municipal purposes.

There are no point source discharges to this reach of the river. The Town of Oxbow's sewage lagoon, located to the southeast of the town and adjacent to the river, does not presently have a direct discharge. However, effluent loss through exfiltration towards the river is suspected. It is presumed that stock also have use of the river valleys. The chief impacts would include normal agricultural runoff, including that from range cattle, together with any groundwater inflows.

.2 Water Quality Observations

Within this reach of the river, the only Canadian station with any significant data base is a primary station south of Glen Ewen, which is utilized by both federal and provincial agencies. This station is approximately 29 km above the border. The United States Geological Survey maintains a station close to the border notated as at Sherwood. For this review, the federal-provincial data at Glen Ewen, together with the U.S. North Dakota information at Sherwood, were utilized. Following are some observations on major parameter groups. Emphasis is placed on the Glen Ewen data, but the Sherwood data are used for comparative purposes or where Canadian information is lacking.

a) Dissolved Salts

- Figure 2.25 indicates median and 25th and 75th percentile values for conductance for both Glen Ewen and Sherwood. The seasonal trends are quite similar and demonstrate increasing levels of conductance from the spring through to the winter. Typical values during the spring were in the range of 800 to 900 uS/cm with increases to around 1000 uS/cm in the summertime. During flow recession in the fall, conductance values climbed to the 1100 to 1200 uS/cm range and under winter conditions, median values of approximately 1600 to 1800 uS/cm could be anticipated. Examination of seasonal paired data over the 1974 - 1984 years for both sites indicate significant variations each way during the spring period. During the summer and fall period, the data tended to be similar, although some years (under low flow conditions) conductances were higher at Glen Ewen. Winter data were rather similar.

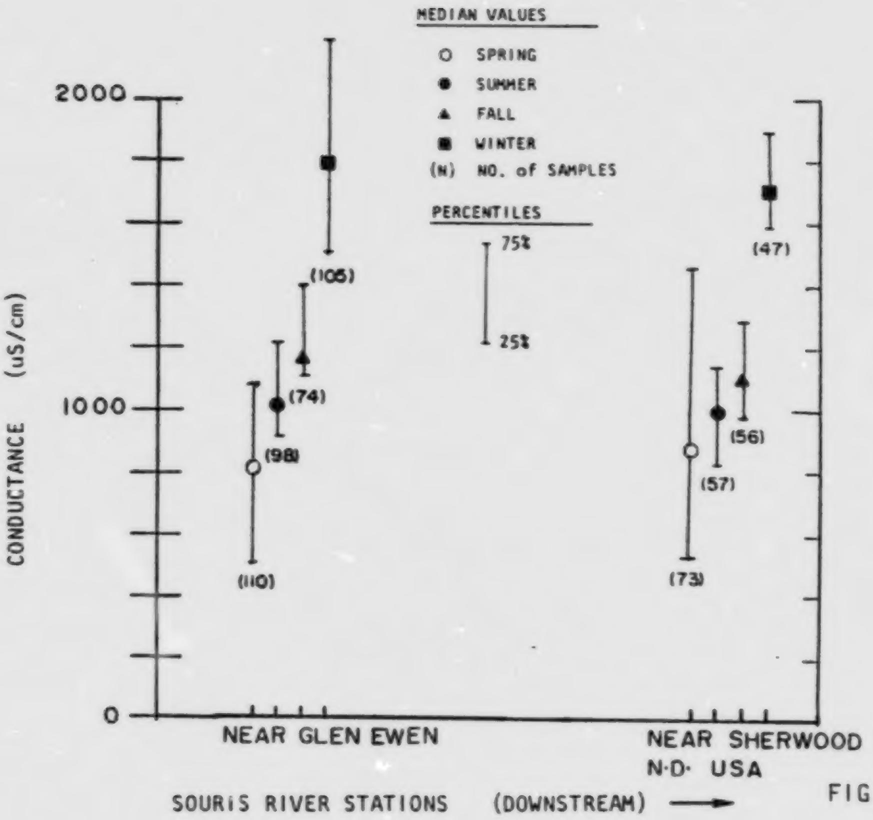


FIG. 2.25

- Data from an automatic, continuous monitor placed at the Glen Ewen site by Environment Canada from 1977 to 1982 yielded the following summary statistics for conductance in uS/cm.(Munro and Crosley 1984)

	n	Median	Range
Spring high flow period	91	643	260 - 1237
Low flow open water period	502	1260	644 - 1714
Low flow under ice cover period	156	1583	878 - 2142

- Based on Environment Canada and USGS data, the calculated relationships between conductance and total dissolved solids (TDS - expressed as sum of dissolved ions) were -

Glen Ewen: TDS = 0.766 x Cond. + 38 (n = 115; r = 0.949)
Sherwood: TDS = 0.887 x Cond. - 55 (n = 64, r = 0.983)

- Median chloride values for Glen Ewen (as shown on Figure 2.26) showed similar seasonal variations to that observed for conductance, but the ranges were relatively more substantial.

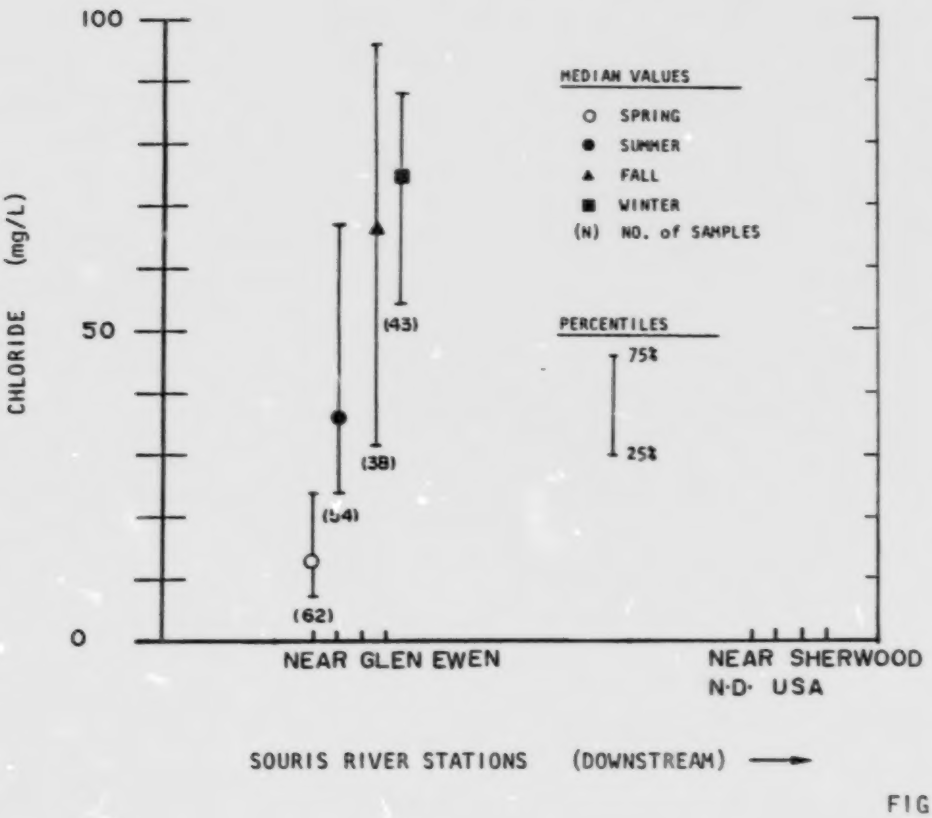


FIG. 2.26

Spring and summer median values were typically below 20 and 30, and 40 mg/L respectively, but during the fall and winter periods, median values ranged from approximately 65 to 75 mg/L. Comparison with the USGS data was similar to that observed for conductance. However, during the wintertime, chloride values tended to be high at Glen Ewen.

- Based on 1975-76 and 1982-84 major ion data at Glen Ewen, the primary cations varied among calcium, magnesium, and sodium. During the winter period, sodium tended to dominate, followed by magnesium and calcium. However, during the higher flow periods, calcium, followed by magnesium and sodium, sometimes predominated. However, on balance, the overall summer through winter periods indicated a high percentage of sodium--often greater than 50% of all of the cations. Of the anions, bicarbonate and sulphate comprised in excess of 90%. Bicarbonate tended to have a higher proportion during the spring runoff periods but in fall and winter, sulphate periodically had a higher percentage than that of bicarbonate. Sodium adsorption ratios calculated over the 1982 - 1984 spring and summer periods ranged from 1.1 to 4.4. At Sherwood, over comparable time periods, sodium similarly dominated the cation species. The SAR values for spring and summer ranged from 2 to 5.

b) Nutrients

- Seasonal median, and 25th and 75th percentile data for total phosphorus are plotted on Figure 2.27 for both the Glen Ewen and Sherwood sites. Both stations exhibit high spring and summer values with decreases during the fall and winter. Median ranges at Glen Ewen for spring and summer were 0.18 and 0.17 mg/L respectively, while for Sherwood, increases to 0.21 and 0.22 mg/L were noted. During the fall Glen Ewen median values dropped to 0.09 while Sherwood values were slightly higher at 0.13 mg/L. Winter values were in a similar range to that observed for the fall. Based on comparative seasonal data over the 1974 to 1983 years for both sites, it was noted that variabilities were encountered both ways during the spring. Summer, fall, and winter data tended to be relatively similar.

- Total kjeldahl nitrogen median and percentiles for both sites are plotted on Figure 2.28. The Sherwood data demonstrated much greater seasonal variability than that recorded for Glen Ewen. Typically, total kjeldahl nitrogen tended to decrease from the spring through fall seasons with increases measured during the winter period. Median values at Glen Ewen for the spring through fall seasons were relatively close and ranged from 1.25 mg/L in the spring to 1.1 mg/L during the

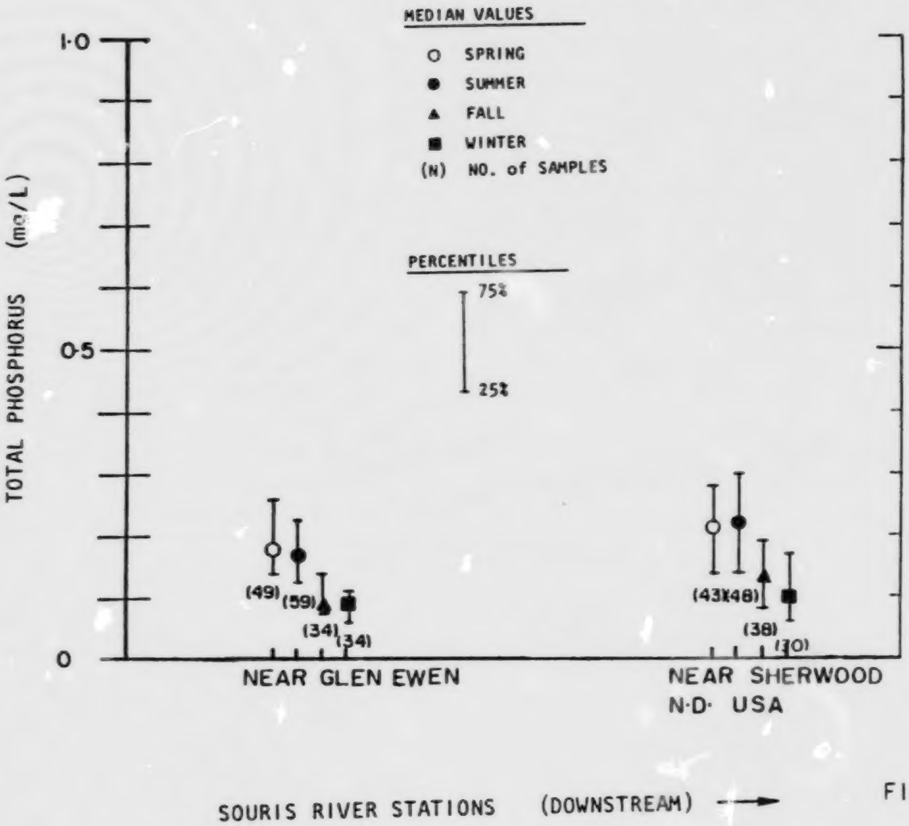


FIG. 2.27

fall. In the wintertime, median values of 1.8 were recorded. The data from Sherwood ranged from approximately 1.9 mg/L in the spring to 1.2 mg/L in the fall. Winter data were somewhat compatible. Based on a 1974-1977 review of similar seasonal data, the only significant differences observed between the two sites were during the fall and winter seasons. Both positive and negative variations occurred.

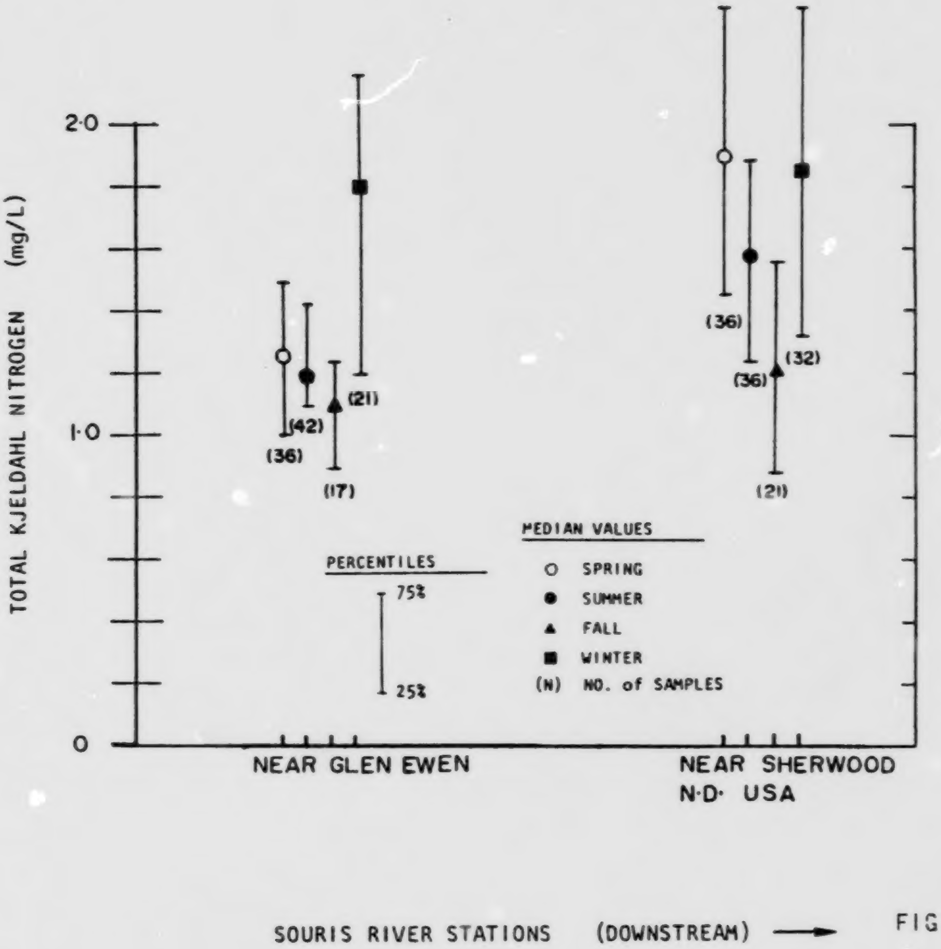


FIG. 2.28

- Ammonia nitrogen data for Glen Ewen was restricted to a small data base. Medians ranged from 0.1 mg/L in the summer to 0.80 mg/L in the winter. Using limited corresponding pH and temperature data, potential un-ionized ammonia concentrations were found to be very low with a maximum of only 0.002 mg/L. At Sherwood, with a greater data base, median ammonia values were found to range from 0.04 mg/L in summer to 0.47 mg/L during the winter. The maximum 90th percentile was 1.06 mg/L (winter). Estimated un-ionized ammonia nitrogen values were generally much less than 0.01 mg/L.

c) Dissolved Oxygen

- Median dissolved oxygen values for Glen Ewen are shown on Figure 2.29. Median values for the spring tended to be reasonably high at 8.8 mg/L but during the summer dropped to 7 mg/L. This is increased to 9.9 mg/L in the fall, but the winter median values were only 4.7 mg/L.

- Compared with Sherwood data over the period 1974 to 1981, seasonal assessments indicated reasonably similar concentrations during the summer and fall, variations in both directions during the spring; and in the wintertime, there was a tendency for lower reported values at the downstream site.
- Based on the available information at Glen Ewen, 23 winter, 2 summer, and 2 fall samples out of a total of 192 provincial and federal data points had dissolved oxygen levels less than 5 mg/L. From the USGS data, 41 winter, 2 spring, 3 summer, and 2 fall samples out of a total of 207 had levels below 5 mg/L.

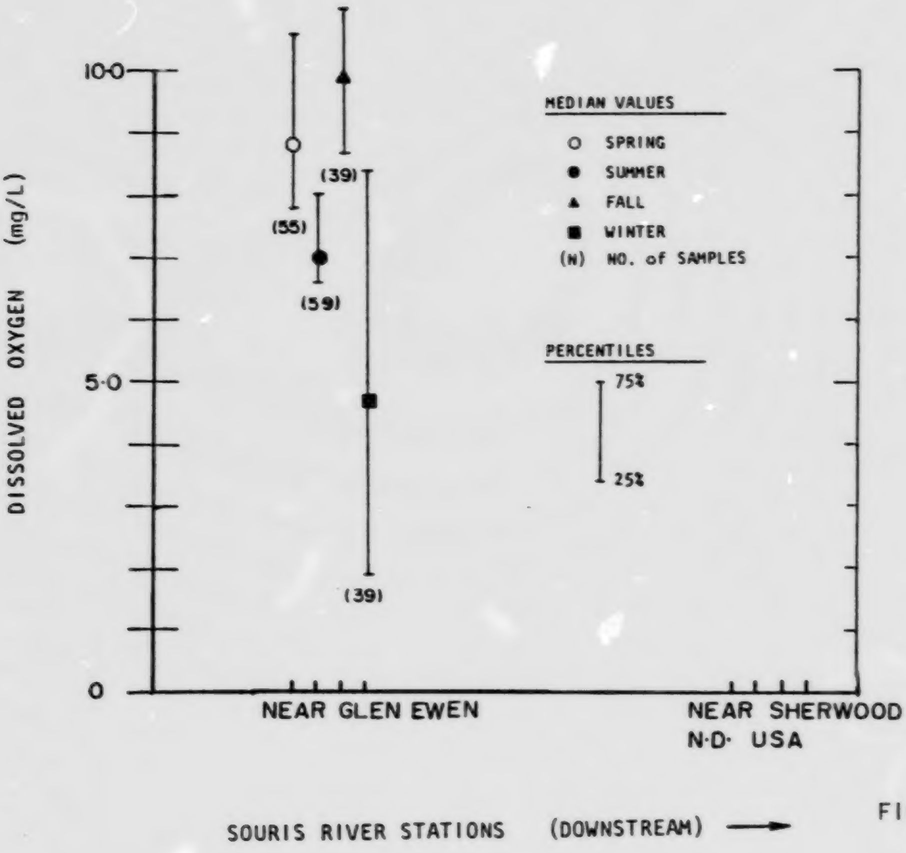


FIG. 2.29

- Although the reliability of the data over the entire 1977-82 monitoring period has been questioned, the Environment Canada automatic monitor at Glen Ewen suggested summer diurnal fluctuations of up to 8 mg/L.(Munro and Crosley 1984) Summary statistics produced the following dissolved oxygen concentrations (in mg/L) over the duration of operation:

	n	Median	Range
Spring high flow period	75	8.7	3.0 - 14.9
Low flow open water period	416	7.1	3.2 - 12.6
Low flow under ice period	135	7.2	1.0 - 14.9

d) Heavy Metals/Trace Substances

- Heavy metal and trace substance data are available for both the Glen Ewen, Saskatchewan, and Sherwood, North Dakota, stations. For many of the variables, a considerable amount of data are available. Summaries are presented for each station in Table 2.14 and 2.15.
- Much of the Canadian data are measured as the extractable form although a few of the parameters are expressed as dissolved. Generally for most of the heavy metals, the concentrations were relatively low. Periodic somewhat high detections had been observed for cadmium, copper, lead, mercury, and zinc. Extractable iron and manganese values have also been quite high. Of other substances, dissolved cyanide (measured as total cyanide), fluoride, and boron have yielded some significant concentrations. Boron values have been measured as high as 1.2 mg/L. During the spring, summer, and fall periods, 2 out of 61 samples had levels in excess of 0.5 mg/L.

TABLE 2.14

HEAVY METALS/TRACE SUBSTANCES

EXISTING QUALITY SUMMARY

Moose Mountain Creek to International Border (Glen Ewen)

		Data Base							
				Seasonal Distr.					
Parameter	Form	Period	Samples	Sp	Su	F	W	Range (mg/L unless noted)	Comments
Al	E	June 7/72 to Jan 5/78	39	12	10	6	11	L0.10 - 0.92	7 @ L0.10
As	D	June 7/72 to June 13/83	77	21	18	17	21	L0.005 - 0.036	8 @ L0.005
Ba	E	June 7/72 to July 10/84	68	21	17	11	19	L0.05 - 0.3	23 @ L0.1 4 @ L0.05 -winter values tend to be in upper range.
Be	E	July 29/75 to Jan 5/78	13	1	5	3	4	L0.01	13 @ L0.01
B	D	Mar 1/71 to Sept 20/83	83	21	22	18	22	0.14 - 1.2	-winter values tend to be in upper range.
Cd	E	Mar 1/71 to Mar 18/80	68	20	18	12	18	L0.001 - 0.014	57 @ L0.001 2 @ L0.002
Cr	E	June 7/72 to Jan 5/78	41	11	13	7	10	L0.010 - L0.015	20 @ L0.015 19 @ L0.010
Co	E	Mar 1/71 to Mar 18/80	71	21	19	11	20	L0.001 - 0.004	31 @ L0.002 15 @ L0.001
Cu	E	Mar 1/71 to Mar 18/80	71	22	18	11	20	L0.001 - 0.087	2 @ L0.001
CN^-	D	Feb 6/75 to Dec 19/84	84	21	22	18	23	L0.001 - 0.057	7 @ L0.005 3 @ L0.001
F	D	July 2/69 to Sept 20/83	215	66	57	39	53	L0.05 - 0.49	4 @ L0.05
Fe	E	June 7/72 to Mar 18/80	69	21	18	10	20	L0.04 - 3.00	1 @ L0.04 -fall values tend to be in lower range
	T	July 30/74	1	1	0	0	0	0.8	
Pb	E	Mar 1/71 to Mar 18/80	68	20	18	11	19	L0.001 - 0.14	41 @ L0.004 18 @ L0.001 -spring values tend to be in higher range.
Mn	D	Apr 4/72 to Dec 19/84	20	5	7	3	5	L0.01 - 0.96	3 @ L0.01 -winter values tend to be in higher range.
	E	Mar 1/71 to Mar 18/80	68	20	18	10	20	L0.01 - 3.20	2 @ L0.01 -winter values tend to be in higher range.
	T	July 30/74	1	1	0	0	0	0.02	
Hg	E	Mar 1/71 to Mar 5/79	64	19	19	10	16	L0.02 - 0.26 (ug/L)	35 @ L0.05 16 @ L0.02 -spring & summer values tend to be in higher range.
	T	Apr 18/79 to Dec 19/84	58	17	15	12	14	L0.02 - 5.00 (ug/L)	36 @ L0.02 -one extreme spring value (5.00)
Mo	E	Jan 31/73 to Aug 5/73	29	9	8	4	8	L0.05 - L0.10	8 @ L0.10 21 @ L0.05
Ni	E	Mar 1/71 to Jan 5/78	41	13	10	6	12	L0.001 - 0.035	1 @ L0.002 5 @ L0.001
Se	D	Jan 3/73 to May 13/83	71	19	19	14	19	0.0003 - 0.0034	16 @ L0.0005 15 @ L0.001
Ag	E	June 7/72 to Feb 6/75	25	10	5	3	7	L0.004 - 0.07	2 @ L0.004 21 @ L0.01 -two values above detection limits in W. winter.
Sr	E	Mar 1/71 to Jan 5/78	38	11	9	6	12	0.15 - 1.46	-winter values tend to be in higher range.
V	E	Jan 31/73 to Mar 18/80	55	18	13	8	16	L0.001 - L0.05	20 @ L0.05 4 @ L0.001
Zn	E	Mar 1/71 to Mar 18/80	71	21	18	11	21	L0.001 - 0.11	1 @ L0.01 15 @ L0.001

Notes:
1) L - less than
2) Sp - spring F - fall
Su - summer W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

TABLE 2.15

HEAVY METALS/TRACE SUBSTANCES

EXISTING QUALITY SUMMARY

Moose Mountain Creek to International Border (Sherwood, North Dakota)

Parameter	Form	Data Base						Range (mg/L unless noted)	Comments
				Seasonal Distr.					
		Period	Samples	Sp	Su	F	W		
Al	D	Nov 13/75 to July 16/86	32	12	5	10	5	0 - 0.05	2 @ L0.10 4 @ L0.01 2 @ 0
As	D	May 16/74 to July 16/86	27	11	3	10	3	L0.001 - 0.008	1 @ L1
Ba	D	Nov 13/75 to July 16/86	26	10	3	10	3	0.044 - 0.200	8 @ L0.100
Be	D	Nov 13/75 to Mar 31/81	12	6	0	6	0	0 - L0.010	7 @ L0.010 2 @ L0.001 3 @ 0
B	D	Apr 19/72 to Aug 28/86	126	39	32	25	30	0.040 - 1.100	
Cd	D	Nov 13/75 to July 16/86	30	12	3	10	5	0 - L0.003	2 not detected. 2 @ 0
Cr	D	Nov 13/75 to July 16/86	31	12	4	10	5	0 - 0.010	8 not detected. 2 @ 0 15 @ L0.010
Co	D	Nov 13/75 to July 16/86	31	12	4	10	5	0 - 0.003	4 not detected. 2 @ 0
Cu	D	May 16/74 to July 16/86	32	13	4	10	5	0 - 0.005	2 not detected. 1 @ 0 1 @ L0.020
CN^-	D	Nov 13/75 to July 16/86	30	12	3	10	5	0.00 - L0.01	9 @ 0.00 21 @ L0.01
F	D	Nov 13/75 to Aug 28/86	90	27	27	21	15	0.0 - 0.40	
Fe	D	Apr 19/72 to July 16/86	59	22	11	15	11	L0.001 - 3.20	8 @ L0.010
Pb	D	May 16/74 to July 16/86	31	12	4	10	5	0 - 0.012	3 not detected. 1 @ L0.200 2 @ 0
Li	D	Nov 13/75 to July 16/86	31	12	4	10	5	0.017 - 0.090	
Mn	D	Apr 19/72 to July 16/86	59	22	11	15	11	0.003 - 4.00	4 @ L0.010
Hg	D	Nov 13/75 to July 16/86	31	12	4	10	5	0 - 0.002 (ug/L)	5 @ L0.005
Mo	D	Nov 13/75 to July 16/86	31	12	4	10	5	L0.001 - 0.006	2 @ L0.010
Ni	D	Nov 13/75 to July 16/86	31	12	4	10	5	0 - 0.007	1 @ L0.002 1 @ L0.001
Se	D	May 16/74 to July 16/86	32	13	4	10	5	0 - 0.002	19 @ L0.001
Ag	D	Nov 13/75 to Mar 31/81	12	6	0	6	0	0.000	8 not detected. 4 @ 0
Sr	D	Nov 13/75 to July 16/86	26	8	6	7	5	0.140 - 0.640	
V	D	Nov 13/75 to July 16/86	29	11	4	9	5	0 - 0.006	6 @ 0
Zn	D	May 16/74 to July 16/86	31	13	4	10	4	0.002 - 0.060	1 not detected. 4 @ L0.020 3 @ L0.003 1 @ L0.012

Notes: 1) L - less than
2) Sp - spring   F - fall
Su - summer   W - winter
3) Form - T - Total
D - Dissolved
E - Extractable

- The USGS data at Sherwood, listed in Table 2.15, contains most of the parameters as measured in the dissolved form due to the most extensive data base available. Subsequently the data between the two sites can not be specifically correlated. Except for some incidents where high manganese and iron have been observed, most of the dissolved heavy metals at Sherwood were detected only at relatively low concentrations. Dissolved boron over approximately 14 years of measurement has shown a considerable range with values up to 1.1 mg/L recorded. Over the spring, summer, and fall periods, 6 out of 96 samples have values in excess of 0.5 mg/L. Three, or 100% of the winter samples exceeded this number.

e) Biocides and Organochlorine Compounds

- A number of samples have been analyzed for biocides and organochlorine compounds at Glen Ewen and at the American Sherwood station. Due to uncertainties in terms of methodologies and variations in the scope of constituents determined, summaries for each site are prepared separately in Tables 2.16 and 2.17. At the Glen Ewen site, based on federal data, the only detections were 2,4-D, 2,4,5-T, lindane, and alpha-BHC. 2,4-D was detected at levels greater than 0.004 ug/L in 61% of the samples with a maximum up to 0.79 ug/L. 2,4,5-T was only in excess of detection limits on 6% of the samples. The pesticides lindane and alpha-BHC were also commonly measured albeit at low levels. The isomer, alpha-BHC, detected in excess of 0.01 ug/L to 0.02 ug/L approximately 96% of the time. Lindane was somewhat less prevalent and trace amounts (up to 0.004 ug/L) were measured 48% of the time.

- At the Sherwood site, USGS data indicates very low incidence of detections for chlorinated pesticides including chlordane, DDT, and dieldrin, heptachlor, and heptachlor epoxide (one sample each only). 2,4-D and 2,4,5-T were also detected with 2,4-D being the most prevalent. All other constituents were reported as not detected over the years 1975 to 1981.

TABLE 2.16

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Moose Mountain Creek to International Border (Glen Ewen)

Parameter	Data Base						Range (ug/L unless noted)	Comments
	Period	Samples	Seasonal Distr.					
			Sp	Su	F	W		
2,4-D	Jun 07/72 to Dec 19/84	110	33	29	20	28	L0.004 - 0.79	43 @ L0.004 -highest values in spring and summer.
2,4,-DB	Sep 13/72 to Dec 19/84	111	32	29	21	29	L0.006 - L0.009	109 @ L0.009 2 @ L0.006
2,4-DP	Sept 13/72 to Dec 19/84	110	32	29	20	29	L0.002 - 0.015	107 @ L0.004 1 @ L0.002 -2 values above detection limit in winter.
2,4,5-T	Jun 07/72 to Dec 19/84	111	33	29	20	29	L0.001 - 0.05	102 @ L0.002 1 @ L0.001 1 @ L0.018
MCPA	Dec 09/72 to Dec 19/84	109	32	28	20	29	L0.2	108 @ L0.2 1 @ L0.0
Silvex	Jun 05/78 to Dec 19/84	63	18	14	13	18	L0.004	63 @ L0.004
Picloram	Oct 03/78 to Dec 19/84	57	15	13	11	18	L0.2	57 @ L0.2
Aldrin	Oct 20/75 to Dec 19/84	74	19	19	15	21	L0.001	74 @ L0.001
Alpha-BHC	Sep 04/75 to Dec 19/84	83	20	22	18	23	L0.001 - 0.020	3 @ L0.001
Gamma-BHC (Lindane)	Mar 01/71 to Dec 19/84	116	32	33	20	31	L0.001 - 0.005	59 @ L0.001 1 @ L0.005
Gamma-Chlordane	Apr 04/78 to Dec 19/84	70	19	18	14	19	L0.002	70 @ L0.002
Dieldrin	Oct 20/75 to Dec 19/84	74	19	19	15	21	L0.002	74 @ L0.002
Endrin	Apr 04/78 to Dec 19/84	70	19	18	14	19	L0.002 - L0.003	69 @ L0.002 1 @ L0.003
Hexachlorobenzene	Jun 05/78 to Dec 19/84	68	17	18	14	19	L0.001	68 @ L0.001
O,P-DDT	Jun 05/78 to Dec 19/84	68	17	18	14	19	L0.001 - L0.004	67 @ L0.001 1 @ L0.004
P,P-DDT	Mar 01/71 to Dec 19/84	105	31	28	17	29	L0.004 - L0.005	104 @ L0.004 1 @ L0.005
Mirex	Jun 05/78 to Dec 19/84	68	17	18	14	19	L0.001	68 @ L0.001
Aroclor 1248 (PCB's)	Dec 09/72 to Feb 26/81	81	21	24	13	23	L0.002 - L0.024	40 @ L0.002 7 @ L0.02 34 @ L0.024
Aroclor 1254 (PCB's)	Dec 09/72 to Aug 22/83	101	28	31	15	27	L0.002 - L0.032	60 @ L0.002 7 @ L0.03 34 @ L0.032
Aroclor 1260	Jun 28/73 to Aug 22/83	88	20	31	15	22	L0.005 - L0.1	60 @ L0.005 20 @ L0.055 7 @ L0.06 1 @ L0.1
Aroclors, Total	Jan 21/80 to Dec 19/84	47	13	13	9	12	L0.002 - L0.02	37 @ L0.002 10 @ L0.02

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

TABLE 2.17

BIOCIDES AND ORGANOCHLORINE COMPOUNDS

EXISTING QUALITY SUMMARY

Moose Mountain Creek to International Border (Sherwood, North Dakota)

Parameter	Data Base						Range (ug/L unless noted)	Comments
			Seasonal Distr.					
	Period	Samples	Sp	Su	F	W		
2,4-D	Nov 13/75 to Mar 31/81	23	6	5	5	7	0 - 0.24	
2,4,5-T	Nov 13/75 to Mar 31/81	23	6	5	5	7	0 - 0.01	1 = 0.01
Silvex	Nov 13/75 to Mar 31/81	23	6	5	5	7	0	
Aldrin	Nov 13/75 to July 7/81	24	6	6	5	7	0	
Chlordane	Nov 13/75 to July 07/81	24	6	6	5	7	0 -0.1	1 = 0.1
Dieldrin	Nov 13/75 to Jul 07/81	24	6	6	5	7	0.0.03	1 = 0.03
Endosulfan	Jan 18/77 to Jul 07/81	19	5	5	3	6	0	
Endrin	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Heptachlor	Nov 13/75 to Jul 07/81	24	6	6	5	7	0 - 0.15	1 = 0.15
Heptachlor Epoxide	Nov 13/75 to Jul 07/81	24	6	6	5	7	0 - 0.02	1 = 0.01
DDT	Nov 13/75 to Jul 07/81	24	6	6	5	7	0 - 0.02	1 = 0.02
DDD	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
DDE	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Methoxychlor	Oct 01/80 to Jul 07/81	4	1	1	1	1	0	
Mirex	Jul 19/78 to Jul 07/81	13	3	4	2	4	0	
Toxaphene	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Diazinon	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Ethion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Malathion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Parathion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Methyl-Parathion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Trithion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
Methyl-Trithion	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	
PCB	Nov 13/75 to Jul 07/81	24	6	6	5	7	0	

Notes: 1) L - less than
2) Sp - spring F - fall
Su - summer W - winter

f) Bacteriology

- Data for total coliforms at Glen Ewen are limited. Median values during the summertime have been recorded at 500 organisms per 100 mL or less. During the fall, the median values were 230 with the high 75th percentile of 2100 per 100 mL.

- Fecal coliform data are similarly sparse. During the fall, median values of 330 coliforms per 100 mL were recorded based on only 6 samples. Limited data on fecal streptococci were also available. The summer median was recorded as 70 organisms per 100 mL.

g) Miscellaneous

- Colour and turbidity data for both Glen Ewen and Sherwood were examined over the periods 1976 to 1981 and 1974 to 1984 respectively. Colour tended to be variable, although values at Glen Ewen were observed to be higher in some years. On the other hand, turbidity data indicated higher values at Sherwood during the summer through winter periods. During the spring, both positive and negative variations were recorded.

- Total organic carbon was also compared on a seasonal basis for the two stations. Generally they were comparable within the period 1974-78 but there were some tendencies for higher concentrations at Glen Ewen.

h) Aquatic Biology

- Data available for this reach is limited to that gathered under the Souris River Basin Study (1978) at the Glen Ewen sampling station.

- Phytoplankton were found to contain primarily green algae (Chlorophyta) and diatoms (Bacillariophyceae) during the spring, summer, and fall, with low but consistent populations of pigmented flagellates (Euglenophyta). Both the green algae and diatoms had wide variety, and diversity indices were high averaging 1.1, although the number of organisms tended to be low. Blue-green algae (Cyanophyta) were found to be only sporadically present.

- Limited chlorophyll$_a$ data were available for the Glen Ewen site. Median summer values were 50 mg/m^3, with ranges up to 26 mg/m^3 (90th percentile). Spring, fall, and winter values tended to be less.

- Zooplankton populations at Glen Ewen were found to consist exclusively of members of the Cladocera and the Copepoda. There were extreme fluctuations in types and numbers of organisms throughout the year and from year to year with a certain species or groups increasing or decreasing to the point of absence from one period to another. However, it was found on balance that a low diversity index of less than 0.1 occurred.(Souris River Basin Study 1978) It is unclear whether this was due to the lack of protective aquatic vegetative habitat or to poor water quality.

- Benthic invertebrates were found to be characterized by dramatic seasonal and annual fluctuations in population types and numbers due to climatological influences.(Souris River Basin Study 1978) Predominant bottom dwellers consisted of Amphipoda, Diptera, Ephemeroptera, Gastropoda, Oligochaeta, and Pelecypoda. The numbers of organisms were quite low and the resulting diversity index of L0.1 may be due to an unsuitable habitat. Significant populations of dipteran larvae, Ephemeroptera, and Pelecypoda had been observed in the fall.(Souris River Basin Study 1978)

- As reported under the Souris River Basin Study (1978), no aquatic vascular vegetation was reported, possibly due to the lack of suitable habitat for rooting of emergent or submergent plants.

.3 Comments

Due to the monitoring activities of Saskatchewan Environment, Environment Canada, and the U.S. agency, a reasonably good water quality data base exists for this reach of the river. In similar fashion to many of the upstream reaches, the water quality in this lower portion is subject to seasonal and flow regime impacts. In particular, the level of conductance or total dissolved salts varies considerably with the seasons. Levels are generally good during spring and summer and deteriorate through the fall and winter. The increases during the fall and winter would be largely attributable to low flows, potential groundwater inputs, and ice cover concentration effects. In addition, some changes over the seasons have been noted with the predominant salt constituents. During the high TDS situations, sodium sulphate normally predominates compared with calcium bicarbonate during high flow and low TDS periods. Periodically high sodium adsorption ratios (G3) have been encountered in the summer period.

Of the nutrients, total kjeldahl nitrogen is also typically higher in the wintertime over that measured during the open water period. In contrast, spring and summer phosphorus values tend to be higher than those observed during the fall and winter. Nevertheless, for both of the nutrients, concentrations appear to be sufficient to provide nutrient sources for aquatic vegetation. Based on limited ammonia data, the un-ionized ammonia concentrations would appear to be quite low.

Dissolved oxygen has been observed to be subject to considerable open water diurnal variations--probably due to oxygen production/ respiration cycles associated with photosynthetic processes. Some incidents of low levels, i.e. below 5 mg/L have been encountered. These are particularly noted under ice cover or non-reaeration conditions.

Information on aquatic biological growths within this reach are essentially limited to the information gathered during the Souris River Basin Study. At that time, typical algal populations and species were found but in types and numbers not normally considered to be a nuisance. Zooplankton and benthic invertebrate populations have shown significant fluctuations. The reported absence of emergent and/or submergent vegetation is postulated to be due to the habitat constraints within the reach.

Water colour has been recorded at high values with the spring and summer seasons generally considerably greater than observed during the fall/winter. Median turbidity levels, based on Glen Ewen measurements, tended to be quite low for all seasons.

With respect to heavy metals and trace substances, available data suggests that these are generally at low levels although some positive detections have been noted. Dissolved boron has been present in the water, but during the irrigation season, generally at levels less than 0.5 mg/L. Typical low level detections of biocides such as 2,4-D, lindane, and alpha-BHC have been noted.

Bacteriological data are inadequate to properly describe the quality from this aspect.

A comparison of applicable parameters for the Glen Ewen monitoring site with Saskatchewan and Canadian water quality objectives/guidelines are presented in Table 2.18. Generally the quality of this reach of the river is in compliance with suggested maximum numbers, although nitrogen, phosphorus, and dissolved salts (periodically) are exceptions. In addition, the fluctuating oxygen levels have provided inferior values to that suggested.

No significant point or diffuse pollution sources have been identified within the reach. The water quality basically reflects that received from upstream sources plus the processes and physical features within and for the reach. Based on the available data, the water quality is generally satisfactory and no major local uses would be unduly impaired.

TABLE 2.18

WATER QUALITY OBJECTIVES AND GUIDELINES

SUMMARY COMPARISONS

MOOSE MOUNTAIN CREEK TO INTERNATIONAL BORDER

	Water Quality Objectives/Guidelines			
Parameter	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Calcium	--	1000 livestock L200 cooling water	48.1 - 78.5*	Values tend to be lower in sp; higher in w.
	(Total Hardness - 800 MDW)	--	(Total Hardness as $CaCO_3$ - 116 - 889.6*)	@ Glen Ewen, 3/215 samples G800 Total Hardness.
Magnesium	200 - MDW	--	25.8 - 56.6*	Values tend to be lower in sp; higher in w.
Sodium	300 - MDW	Depends on crop and soil type for irrigation	81 - 242*	Values tend to be lower in sp; higher in w. @ Glen Ewen 23/310 samples G300, @ near U.S. border 2/3 samples G300.
-% of cations	30 - 75%	--	--	@ Glen Ewen, range is 25 -63%.
-SAR	--	Restriction for irrigation: L3 none 3 - 9 slight - moderate G9 severe	--	@ Glen Ewen, range is 1.1 - 4.4; higher values tend to be in summer.
Chloride	250 - MDW	250 drinking water 100 - 700 irrigation L600 cooling water	13.3 - 74*	Values tend to be lower in sp; higher in w.
Bicarbonate	--	L600 cooling water		
	(Total Alkalinity 500 as $CaCO_3$ - MDW)		(Total Alkalinity as $CaCO_3$ - 214 - 406*)	@ Glen Ewen, 58/384 samples G500 for Total Alkalinity, @ near U.S. border, 1/3 samples G500 for Total Alkalinity.
Sulphate	500 MDW	1000 livestock L680 cooling water	148 - 380*	@ Glen Ewen, 7/159 samples G500.
TDS (Sum of ions)	1500 MDW	500 drinking water 500 - 3500 irrigation	--	@ Glen Ewen 1/1 sample G500.
TKN	1.0 total inorganic and organic N)	10.0 nitrate } drinking w 1.0 nitrite } 100 $NO_3 + NO_2$ } livestock 10 nitrite } 0.06 nitrite - aquatic life	1.1 1.8	Values tend to be higher in winter, @ Glen Ewen, 86/115 samples G1.0.
Ammonia, Total	--	Depends on temp. and pH	0.1 - 0.80*	Values tend to be higher in w. Un-ionized ammonia calculated max. @ Glen Ewen - 0.0016 mg/L.
Phosphorus, Total	0.05 as P	--	0.09 - 0.43*	Values tend to be high in sp and sum, @ Glen Ewen, 165/176 samples G0.05.
Oxygen, Dissolved	5.0 min at any	5.0 - 6.0 warm water 6.5 - 9.5 cold water aquatic biota	4.7 - 9.9*	Very low values in winter, @ Glen Ewen, 27/192 samples L5.0.
Aluminum	--	0.1 if pH 26.5 $[Ca^{2+}]$ ≥4.0 mg/L & DOC ≥2.0 mg/L aquatic life 5.0 - 20.0 irrigation (depends on soil) 5.0 livestock	L0.10 - 0.92	@ Glen Ewen, 13/39 samples G0.1.

TABLE 2.18 (Cont'd)

	Water Quality Objectives/Guidelines			
Parameter	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Arsenic	0.01	0.05 drinking water and aquatic life 0.1 - 2.0 irrigation (depends on soil) 0.5 livestock (5.0 when not added to feed)	L0.005 - 0.036	@ Glen Ewen, 4/77 samples G0.01.
Barium	1.0	1.0 drinking water	L0.05 - 0.3	Values tend to be in upper range in w.
Beryllium	--	0.1 - 0.5 irrigation (depends on soil) 0.1 livestock	L0.01	--
Boron	0.5	5.0 drinking water 0.5 - 6.0 irrigation (depends on crop) 5.0 livestock	0.14 - 1.2	@ Glen Ewen, 18/83 samples G0.5. Values tend to be in upper range in w.
Cadmium	0.01 0.005 MDW	0.005 drinking water 0.2 - 1.8 aquatic life (depends on hardness) 0.01 irrigation 0.02 livestock	L0.001 - 0.014	@ Glen Ewen,5/68 samples G0.005, 2/68 samples G0.01.
Chromium	0.05	0.05 drinking water 0.02 fish; 2.0 aquatic life; 0.1 irrigation 1.0 livestock	L0.010 - 0.011	--
Cobalt	--	0.05 - 5.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.004	--
Copper	0.02	1.0 drinking water 2 - 4 aquatic life (depends on hardness) 0.2 - 1.0 irrigation (depends on crop) 0.5 - 5.0 livestock (depends on animal)	L0.001 - 0.087	@ Glen Ewen, 4/71 samples G0.02.
Cyanide	0.01	0.2 drinking water 5.0 (free cyanide as CN) aquatic life	L0.001 - 0.057	@ Glen Ewen, 2/84 samples G0.01.
Fluoride	1.5 1.5 MDW	1.5 drinking water 1.0 - 15.0 irrigation (depends on soil) 2.0 livestock (1.0 if feed contains fluoride)	L0.05 - 0.49	--
Iron	0.3 0.3 MDW	0.3 drinking water 0.3 aquatic life 5.0 - 20.0 irrigation (depends on soil)	L0.04 - 3.00	@ Glen Ewen, 60/70 samples G0.3. Values tend to be in lower range in f.
Lead	0.05	0.05 drinking water 1 - 7 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 0.1 livestock	L0.001 - 0.14	@ Glen Ewen, 1/68 samples G0.05. Values tend to be in higher range in sp.
Manganese	0.05	0.05 drinking water 0.2 - 10.0 irrigation (depends on soil)	L0.01 - 3.20	@ Glen Ewen, 69/89 samples G0.05. Values tend to be in higher range in w.
Mercury	0.1 ug/L 1 ug/L MDW	1 ug/L drinking water 0.1 ug/L aquatic life 3 ug/L livestock	L0.02 - 5.00 ug/L.	@ Glen Ewen, 4/122 samples G0.1 ug/L, 1/122 samples G1.0 ug/L. Sp and sum values tend to be in higher range.

TABLE 2.18 (Cont'd)

Parameter	Water Quality Objectives/Guidelines Saskatchewan[1] (mg/L unless noted)	 CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Molybdenum	--	0.01 - 0.05 irrigation (depends on soil) 0.5 livestock	L0.05 - L0.10	@ Glen Ewen, 8/29 samples L0.10.
Nickel	--	25 - 150 aquatic life (depends on hardness) 0.2 - 2.0 irrigation (depends on soil) 1.0 livestock	L0.001 - 0.035	--
Selenium	0.01	0.01 drinking water 0.001 aquatic life 0.02 irrigation 0.05 livestock	0.0003 - 0.0034	@ Glen Ewen, 7/71 samples G0.001.
Silver	0.05	0.05 drinking water 0.0001 aquatic life	L0.0004 - 0.07	@ Glen Ewen, 2/25 samples G0.0001, 1/25 samples G0.05.
Vanadium	--	0.1 - 1.0 irrigation (depends on soil) 0.1 livestock	L0.001 - L0.05	--
Zinc	0.05	5.0 drinking water 1.0 irrigation, if soil pH L6.5; 5.0, if soil pH G6.5	L0.01 - 0.11	@ Glen Ewen, 4/71 samples G0.03, 2/71 samples G0.05.
Aldrin & Dieldrin	0.7 ug/L - MDW	0.7 ug/L drinking water 0.004 ug/L (dieldrin) aquatic life	L0.001 aldrin L0.002 dieldrin ug/L	--
Chlordane (Total Isomers)	7 ug/L - MDW	7 ug/L drinking water 0.006 ug/L aquatic life	Gamma - L0.002 ug/L	--
2,4-D	0.1 - MDW	0.1 drinking water 4.0 ug/L aquatic life (phenoxy herbicides)	L0.004 - 0.79 ug/L	Values tend to be higher in sp and sum.
DDT	0.03 - MDW	0.03 drinking water 0.001 ug/L aquatic life	O,P - L0.001 - L0.004 ug/L P,P - L0.004 - L0.005 ug/L	--
Lindane (Gamma-BHC)	4 ug/L - MDW	4 ug/L drinking water	L0.001 - L0.005 ug/L	--
PCB's (Total)	3 ug/L 0.02 ug/L MDW	0.001 ug/L aquatic life	L0.002 - L0.02 ug/L (Total Aroclors)	--

TABLE 2.18 (Cont'd)

	Water Quality Objectives/Guidelines			
Parameter	Saskatchewan[1] (mg/L unless noted)	CCREM - CWQG[2] (mg/L unless noted)	Observed Ranges[3] (mg/L unless noted)	Comments
Coliforms, Total	L5,000/100 mL for potable supply or recreation (not @direct contact) for ≥ 90% of the samples (not ≥ 5 samples/30-d period) -depends on type and degree of pollution, local conditions in watershed. L1000/100 mL geom. mean of 5 samples for direct contact recreation or vegetable crop irrigation for ≤ 20% of the samples in one month, or ≤ 2400/100 mL/day.	1000/100 mL irrigation high quality -livestock	135 - 230/100 mL* (MPN) 500/100 mL*(MF) (provincial data)	@ Glen Ewen, 1/149 samples G5000/100 mL, @ Glen Ewen, 3/149 samples G2400/100 mL, @ Glen Ewen, 8/149 samples G1000/100 mL.
Coliforms, Fecal	L1000/100 mL (see above) L200/100 mL (see above)	--	L23 - 330/100 mL* (MPN) 22/100 mL*(MF) (provincial data)	@ Glen Ewen, 1/129 samples G1000/100 mL, @ Glen Ewen, 15/129 samples G200/100 mL.
pH	6.5 - 8.5 but not 0.5 units over background value	6.5 - 8.5 drinking water 5.0 - 8.3 cooling water	7.7 - 8.2 (field)*	@ Glen Ewen, 5/212 samples G8.5, 27/212 samples G8.3 (field).
Colour	≤ 30 TCU increase above natural value	15 TCU drinking water	30 - 55 relative units	--
Turbidity	≤ 25 NTU over natural turbidity	5 NTU drinking water	4 - 14 JTU*	--
Temperature	≤ 3°C increase above ambient water temp.	15°C drinking water No alterations of thermal stratification or turn-over dates; no exceedences of max weekly ave temp, and no exceedences of max short-term temp.	20°C* (summer)	--

Notes: Objectives/guidelines denote "less than or equal to" values unless otherwise stated.

[1] Saskatchewan Environment Water Quality Objectives, 1983 (Surface Water Quality Objectives)
Saskatchewan Environment Municipal Drinking Water Quality Objectives, June 1980 (MDW)

[2] Canadian Council of Resource and Environment Ministers - Canadian Water Quality Guidelines, March 1987

[3] Observed Ranges - * signifies median ranges.

3. WATER QUALITY PROJECTIONS

3.1 Water Quality Modelling

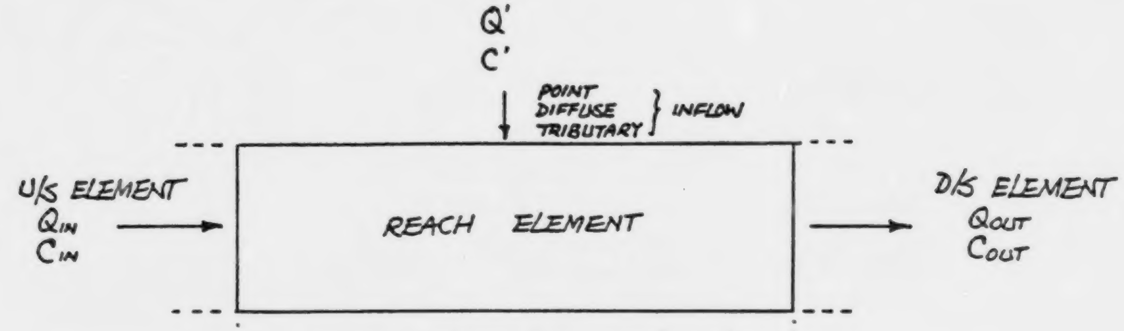
To predict water quality with the reservoirs in place and operating to provide projected uses and demands, a mathematical modelling technique was used for selected characteristics.

3.1.1 Model Description

The Water Quality Planning Model (WQPM) is a stream and reservoir model suitable for predicting steady state river conditions, and seasonal or annual average reservoir quality. Figure 3.1 describes the stream component.

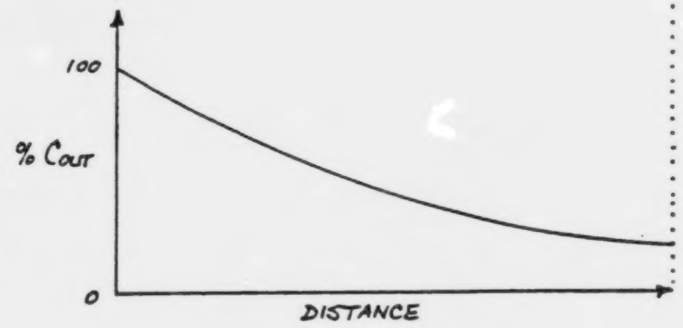
The river system is defined by reaches, each of which is further subdivided into computational elements. Any element can include one point source input (i.e. effluent) or one withdrawal. In addition, diffuse source inflows to a reach can be defined and the model automatically distributes the flow across all reach elements. All inflows and headwaters must be defined for both quantity and quality (up to 10 parameters). The model maintains a flow balance down the system but does not simulate hydraulic conditions, i.e. depth, velocity, time of travel. It is applicable for well mixed systems and uses advection as the only transport mechanism. Lateral and longitudinal dispersion are excluded and as such it is not appropriate for mixing studies or simulation of events, i.e. short-term runoff or batch discharges. Instream processes are simulated by first order decay which may be varied by reach. Winter oxygen can be simulated assuming complete ice cover, therefore zero reaeration, and the oxygen demand is a simple decay against distance. The stream model

WATER QUALITY PLANNING MODEL
REACH COMPONENT


Q'
C'
POINT
DIFFUSE
TRIBUTARY
INFLOW
U/S ELEMENT
Q_{IN}
C_{IN}
REACH ELEMENT
D/S ELEMENT
Q_{OUT}
C_{OUT}

$$C_{OUT} = \frac{Q_{IN} * C_{IN} + Q' * C'}{Q_{IN} + Q'}$$

MIXING MODEL



$$DF = (1.0 - RATE/100.)^{L}$$

$$(C_{OUT})_{FINAL} = C_{OUT} * DF$$

RATE : DECAY RATE (% / Km)
L : ELEMENT LENGTH (Km)

ASSIMILATION MODEL

FIG. 3.1

is suitable for daily, weekly, or monthly average conditions. It can be run in series, i.e. month to month, however the simulated results for one month are not used as input to the next.

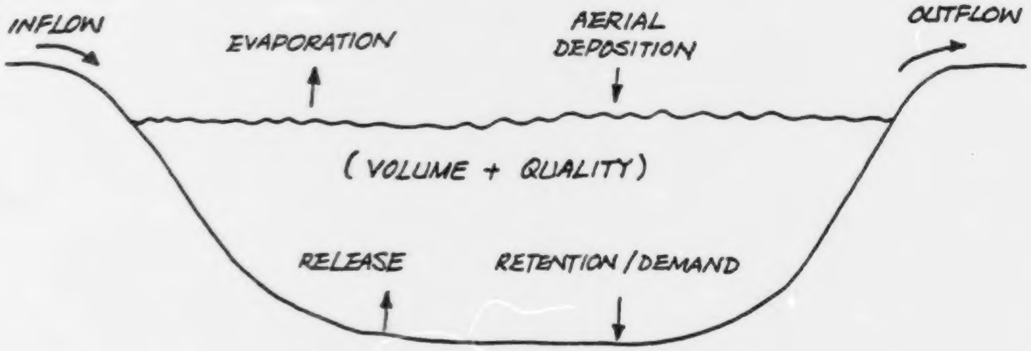
The reservoir model (Figure 3.2) assumes complete mixing of inflows and is best run on a monthly timestep, with the end result being a seasonal or annual average value. It can be run with prescribed outflows, or outflows can be computed in accordance with a storage volume/discharge curve. Evaporation is accounted for. In addition to mass balance of water quality constituents, aerial deposition, sediment retention, or release and time decay can be simulated for any parameter. Winter oxygen depletion is simulated according to a defined daily areal oxygen depletion rate. The model requires input of an area-capacity curve for each reservoir so that surface area and mean depth can be computed for each water level.

3.1.2 Model Application to the Souris River Basin

The model schematic for the application of WQPM to the Souris River Basin is presented in Figure 3.3. The configuration is designed to coincide with the water balance model (WBSM) for the Souris Basin implemented by the Saskatchewan Water Corporation (SWC). WQPM was set up to continuously simulate conditions for the period from 1955-1974 (20 years). This period includes two major high runoff periods and a sequence of low flow years and should be reasonably typical of a long-term potential. In addition, an alternate hydrological regime period was examined (Section 3.3).

Headwater tributary, effluent, and withdrawal flows were extracted from appropriate WBSM runs as provided by SWC. WBSM takes natural historic flows and subtracts on that existing or projecting water demands for all consumptive water uses to estimate reservoir levels and river flows. It

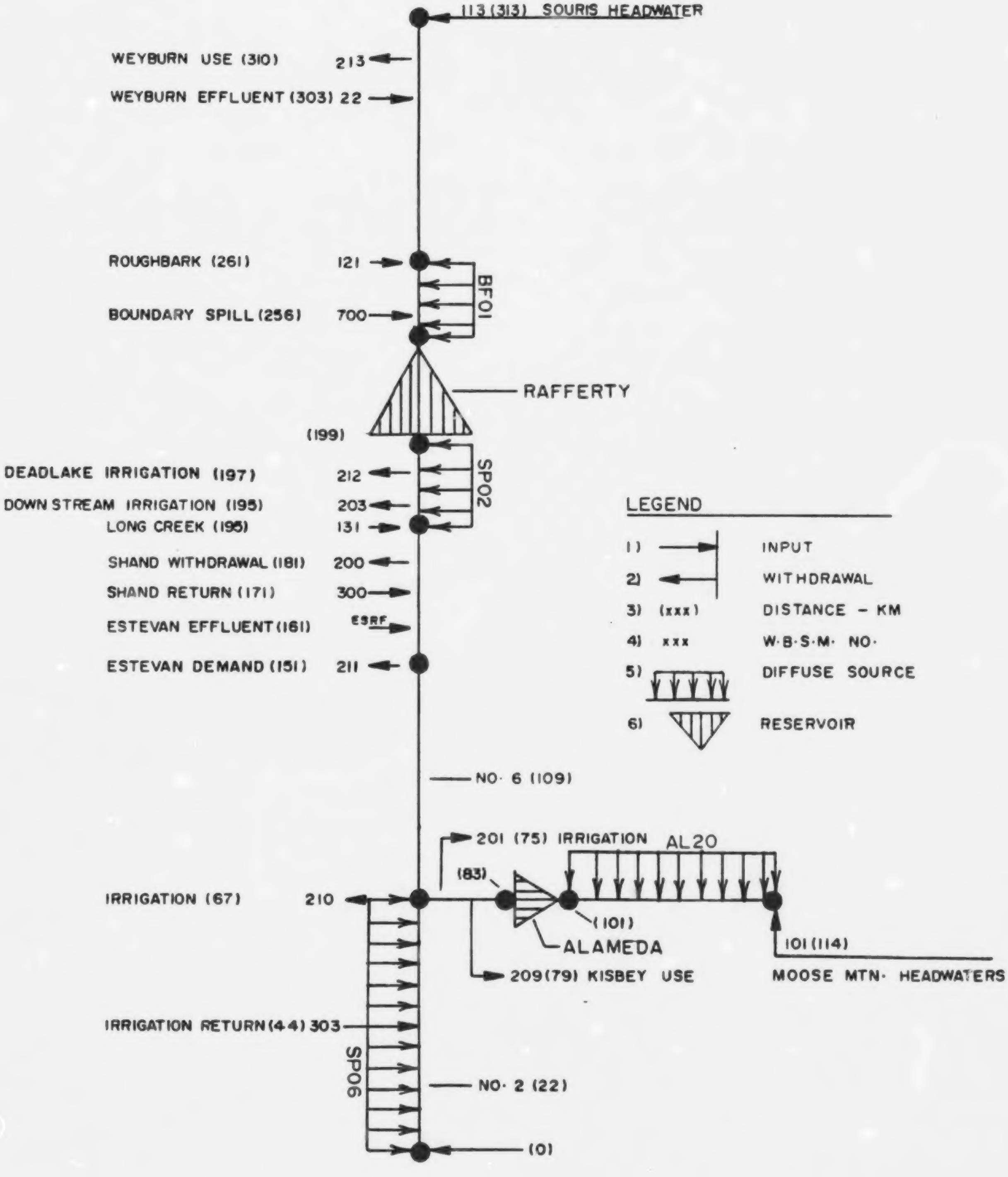
WATER QUALITY PLANNING MODEL
RESERVOIR COMPONENT


INFLOW
EVAPORATION
AERIAL DEPOSITION
OUTFLOW
(VOLUME + QUALITY)
RELEASE
RETENTION / DEMAND

- COMPLETE MIXING
- MONTHLY SIMULATION INTERVAL

$$C_{OUT} = C'_{RES} = \frac{MC + Q_{IN} * C_{IN} + \frac{\overset{\circ}{VOL}_{RES}}{K_T} * C^{\circ}_{RES}}{Q_{IN} + \frac{\overset{\circ}{VOL}_{RES} - EVAP}{K_T}}$$

FIG. 3.2


113 (313) SOURIS HEADWATER
WEYBURN USE (310) 213
WEYBURN EFFLUENT (303) 22
ROUGHBARK (261) 121
BOUNDARY SPILL (256) 700
BF01
RAFFERTY
(199)
DEADLAKE IRRIGATION (197) 212
DOWN STREAM IRRIGATION (195) 203
LONG CREEK (195) 131
SP02
SHAND WITHDRAWAL (181) 200
SHAND RETURN (171) 300
ESTEVAN EFFLUENT (161) ESRF
ESTEVAN DEMAND (151) 211
NO. 6 (109)
201 (75) IRRIGATION
AL20
(83)
(101)
ALAMEDA
101 (114)
MOOSE MTN. HEADWATERS
209 (79) KISBEY USE
IRRIGATION (67) 210
IRRIGATION RETURN (44) 303
SP06
NO. 2 (22)
(0)
LEGEND
1) INPUT
2) WITHDRAWAL
3) (xxx) DISTANCE - KM
4) xxx W.B.S.M. NO.
5) DIFFUSE SOURCE
6) RESERVOIR

SCHEMATIC - WATER QUALITY PLANNING MODEL

FIG. 3.3

has a penalty system whereby allocations can be priorized during periods of supply shortage.

In addition to river flows and reservoir storage from the WBSM, historical water quality monitoring records were used to define headwater and tributary water quality conditions for WQPM. The quality of municipal effluents and diffuse source inflows were similarly determined. In the process, the following assumptions were made:

- The parameters modelled include total phosphorus (TP), total kjeldahl nitrogen (TKN), chloride (Cl), electrical conductance (COND), sodium (Na), magnesium (Mg) and calcium (Ca). Winter oxygen was also predicted for Rafferty and Alameda reservoirs.
- Souris River headwater quality was based upon monthly average observed data for the site below Nickle Lake, using the combined Federal and Provincial data bases.
- The quality of inflow from Roughbark Creek was based upon monthly average historical data for the federal monitoring site - located 2.4 km west of Midale.
- The Moose Mountain Creek headwater quality was defined by monthly average provincial and federal data from Highway No. 18 west of Oxbow.
- Quality of water released from Boundary Reservoir was defined by monthly average combined provincial and federal data for Long Creek near Estevan.
- Effluent quality for Estevan and Weyburn municipal effluents are based upon review of provincial effluent monitoring data (Table 3.1).

Table 3.1. Estimated municipal effluent water quality.

	WEYBURN		ESTEVAN	
	JAN - JUNE	JULY - DEC	JAN - JUNE	JULY - DEC
Conductance (usie/cm)	2000	2500	2500	2100
TKN (mg/l)	25	17	20	7
TP (mg/l)	4	2	7	3.5
Cl (mg/l)	140	150	200	180
Ca (mg/l)	78	117	65	78.5
Mg (mg/l)	57	145	45	55
Na (mg/l)	282	548	300	373

- The municipal effluent flows (m^3/s) were set at:

	APRIL		OCTOBER	
	Calibration	Future	Calibration	Future
Estevan	0.11	0.292	0.115	0.266
Weyburn	-	0.3	-	0.217

- The diffuse source inflow quality is based upon review of existing groundwater data for the region, and surface runoff data during spring snowmelt and major rainfall events (Table 3.2). It was assumed that surface runoff was the major component of diffuse source inflow during spring and early summer, whereas groundwater was the greatest contributor during the low flow conditions experienced in late summer, fall and winter.

Table 3.2 DIFFUSE SOURCE INFLOW QUALITY
(SURFACE RUNOFF - GROUND WATER)

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
TKN (mg/l)	0.1	0.1	1.5	2.0	1.8	1.6	1.6	1.6	1.6	1.6	0.1	0.1
TP (mg/l)	0.051	0.05	0.25	0.2	0.25	0.3	0.3	0.3	0.3	0.2	0.05	0.05
Cond. (usie/cm)	1000	1000	250	200	200	250	300	300	300	250	1000	1000
Cl (mg/l)	25	25	6	4	4	6	10	12	10	6	25	25
Ca (mg/l)	260	260	20	20	20	20	25	25	20	20	260	260
Mg (mg/l)	100	100	8	8	8	8	10	10	8	8	100	100
Na (mg/l)	300	300	9	9	9	9	12	12	9	9	300	300

To calibrate WQPM, it was run for the historical condition (1955 - 1974). The headwater flows for the Souris River and Moose Mountain Creeks were those defined in the water balance run for 50% apportionment and maximum irrigation expansion. These should adequately approximate historical conditions since they are upstream of major irrigation demands, and water withdrawals for thermal power generation. The flows in Long Creek (releases from Boundary Reservoir) were set equal to recorded flows. The historical effluent flows from Weyburn and Estevan were estimated from historical records maintained by Saskatchewan Environment. The calibration run did not include simulation of Alameda and Rafferty Reservoirs, and the irrigation/thermal demands were set to zero. No channel decay or re-suspension were assumed, therefore the simulated results are essentially a simple mass balance of defined inflows.

There are times when channel flows in the Souris River basin are zero. During those periods WQPM automatically sets the water quality equal to zero. These zero values are excluded from subsequent statistics and plots.

Figures 3.4 to 3.10 (appended) present the calibration run results for the Souris River at Glen Ewen. The plots compare monthly average concentrations, and corresponding standard deviations, as simulated by WQPM for 1955 to 1974, with monthly average observed data over the entire monitoring interval. Electrical conductivity is slightly underestimated during spring and summer, while there is a greater deviation between predicted and observed during winter months. The seasonal pattern for sodium, calcium, magnesium and chloride is generally similar to that of conductivity. The general agreement between predicted and observed varies somewhat by parameter, but is generally adequate considering the available data and the intermittent nature of the system. The calibration could be improved by refining the estimate of diffuse source inflow rates and quality, and consideration of elevated winter salinities caused by freeze-out. However, site specific data on both these items are limited.

The simulated nitrogen and phosphorus conditions are generally adequate for most months except September, October, and November when concentrations are over-approximated relative to observed data. This partially reflects the October release of municipal effluents from Estevan. The model assumes the effluent waters are transported through the system, when in actuality much of the discharge may be retained along the system. Stream flows in late fall and winter are exceptionally low, which also complicates the simulation. In terms of mass loading, most nutrients are transported during spring and early summer when river flows are greatest.

3.2 Simulated Water Quality Conditions - Scenario 1

The WQPM model for the Souris River Basin, as described in Section 3.1, was modified as follows to predict water quality conditions for the proposed reservoirs and downstream river channel:

1) Alameda and Rafferty Reservoirs were defined according to the area - capacity curves included in the WBSM model. The dam for Rafferty was assumed to be 7.7 km upstream of the confluence of the Souris River and Long Creek. Alameda dam was located 16 valley km upstream of the confluence of Moose Mountain Creek and the Souris River. General characteristics of each reservoir are described in Table 3.3.

2) The water balance condition included the following:

    - foreseeable future water demands for municipal water use and thermal demand.
    - 2025 ha irrigation development from Rafferty and 2835 ha from Alameda.
    - 50% apportionment
    - no evaporative credit
    - 70% reliability for irrigation
    - no groundwater pumping from the Estevan aquifer.
    - all spills of water from Boundary Reservoir were routed to Rafferty.

Table 3.3 Physical Characteristics of Proposed Reservoirs

	ALAMEDA	RAFFERTY
FSL (m)	574	550.5
Area at FSL (m^2)	13.3 X 10^6	^{4}9 X 10^6
Volume at FSL (m^3)	100 X 10^6	435 X 10^6
Average depth (m)	7.5	8.9
Maximum depth (m)	24	15.5

3) Effluent flows from Estevan and Weyburn were scaled up to possible future conditions. Discharges from each were assumed to occur in April and October.

4) Reservoir retention/release for total nitrogen, conductivity and major ions was assumed equal to zero.

5) In addition to inflows and evaporation, phosphorus concentrations in each reservoir were effected by atmospheric deposition and settling. A nominal sediment release of phosphorus was also defined for July and August. Table 3.4 presents all rates.

Table 3.4 Phosphorus coefficients used in modelling Rafferty & Alameda Reservoirs.

	RAFFERTY	ALAMEDA
Atmospheric Deposition[1] (mg/m^2/month)		
May - November	1.82	1.82
April	9.1	9.1
Phosphorus Settling[2] (1/day)		
Continuous	0.0047	0.0063
Sediment Release[3] (mg/m^2/day)		
July - August	4.0	2.0

1 Mitchell 1985
2 Mancini et al. 1983
3 Review of literature for prairie lakes and reservoirs.

3.2.1 Rafferty and Alameda Reservoirs' Quality

Simulated results (1955 - 1974) for Rafferty and Alameda reservoirs are presented in Figures 3.11 to 3.18. Summary statistics are presented in Table 3.5. In each case, the reservoir is projected to be filled and flushed by high runoff early in the time series, there is then a sequence of normal and low flow years until spring of 1969 when runoff is again substantial.(Figures 3.19, 3.20)

Table 3.5 Predicted average reservoir water quality. (Bracketed values are standard deviations.)

	RAFFERTY	ALAMEDA
TP (mg/l)	0.049 (0.025)	0.038 (0.024)
TKN (mg/l)	3.00 (0.69)	2.18 (0.27)
Cond (usie/cm)	559 (125)	525 (140)
Ca (mg/l)	45 (9)	40 (7)
Mg (mg/l)	24 (5)	24 (7)
Na (mg/l)	47 (14)	46 (18)
Cl (mg/l)	18 (4)	10 (3)
SAR	1.4(0.3)	1.4(0.4)

Conductivity is a measure of total salinity. Values in Alameda remain relatively constant between 300 and 700 usie/cm, reflecting inflow quality, evaporation and an average water residence time of 20 years. Conductivity values in Rafferty are forecast to be more variable due to its longer water residence time (9.3 years) and greater evaporative loss of water. Between 1955 and 1968 values gradually increase from 350 usie/cm to a maximum of 900 usie/cm. This is followed by a substantial drop in 1969 caused by a major dilution event associated with a high spring runoff.

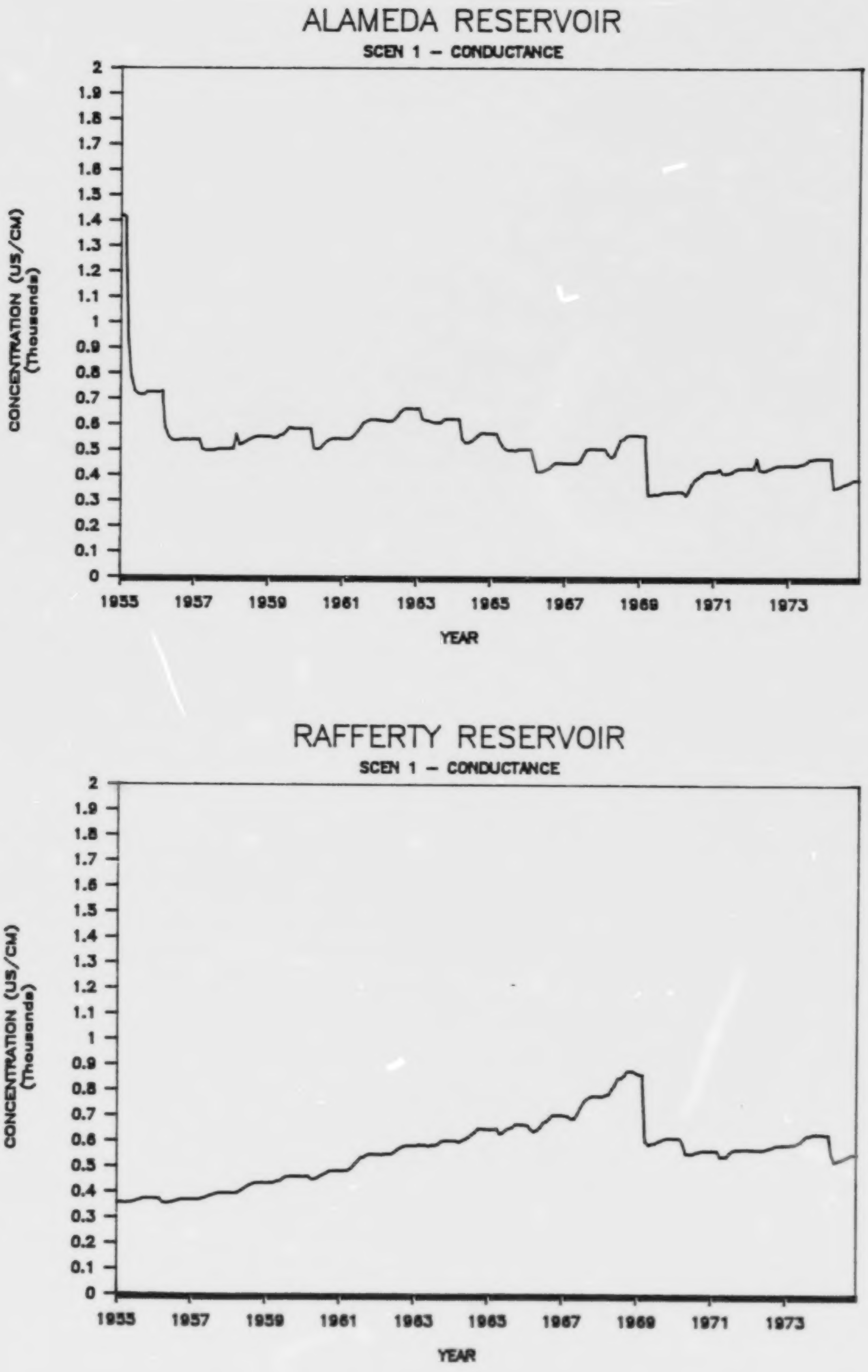
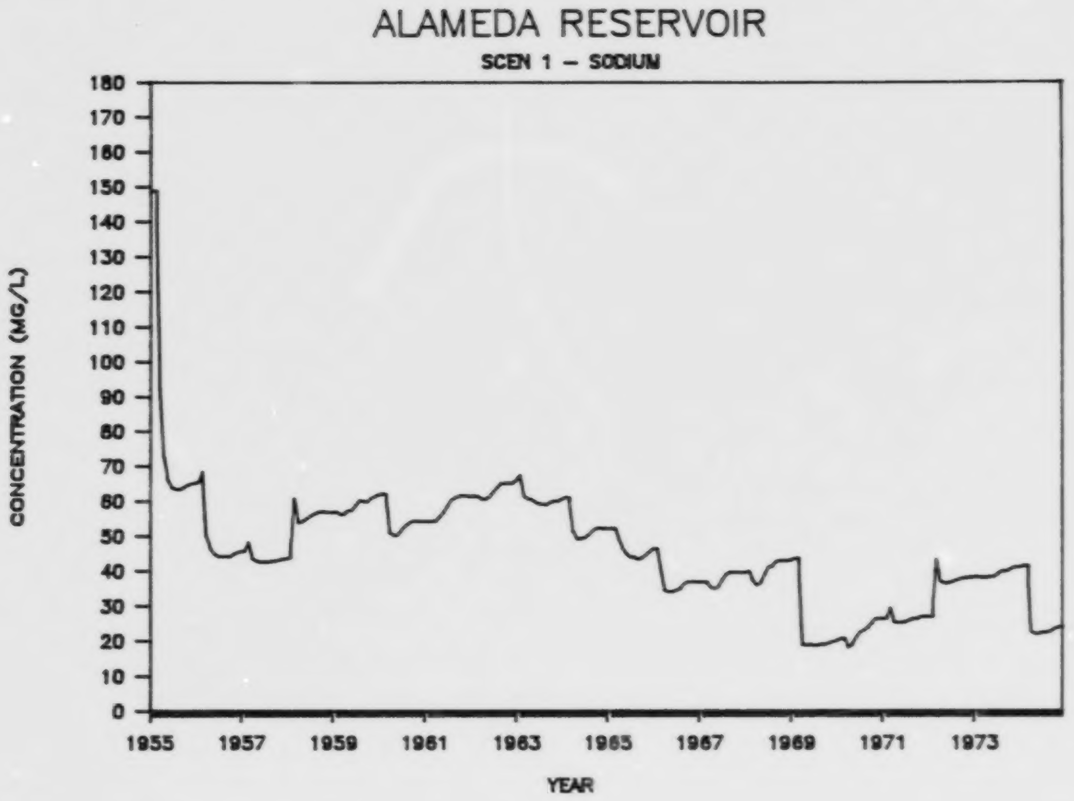

ALAMEDA RESERVOIR
SCEN 1 – CONDUCTANCE
CONCENTRATION (US/CM)
(Thousands)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR
RAFFERTY RESERVOIR
SCEN 1 – CONDUCTANCE
CONCENTRATION (US/CM)
(Thousands)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.11


ALAMEDA RESERVOIR
SCEN 1 – SODIUM
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

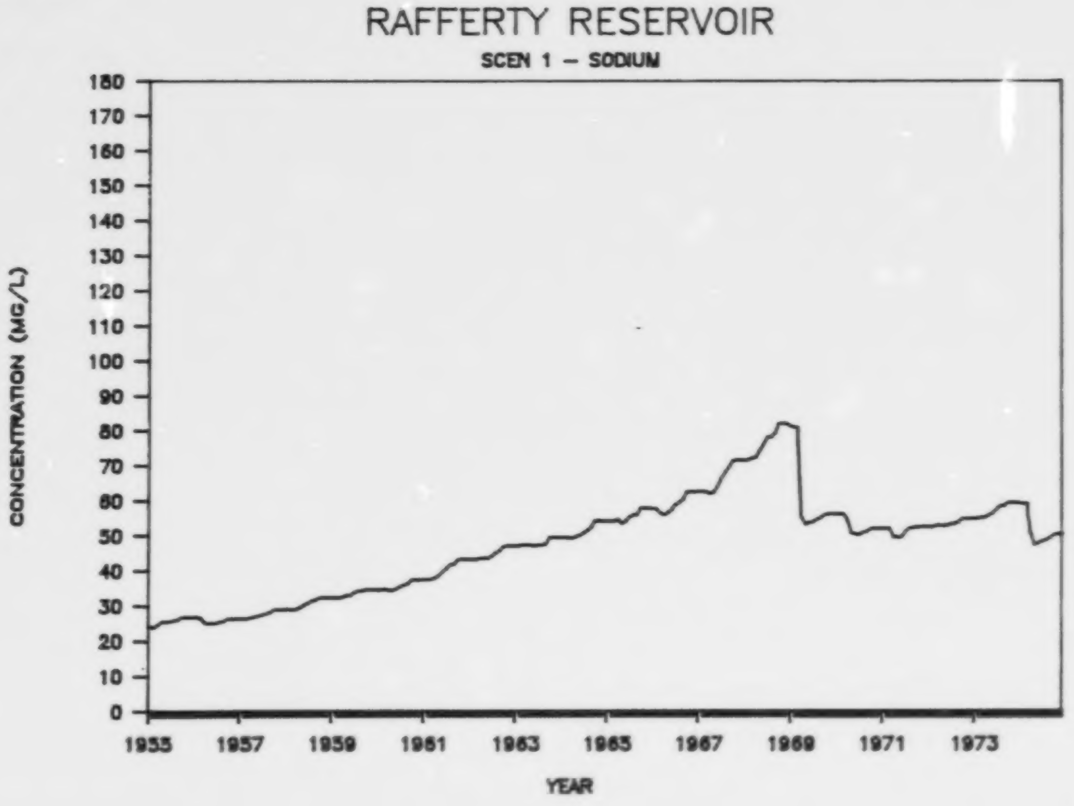
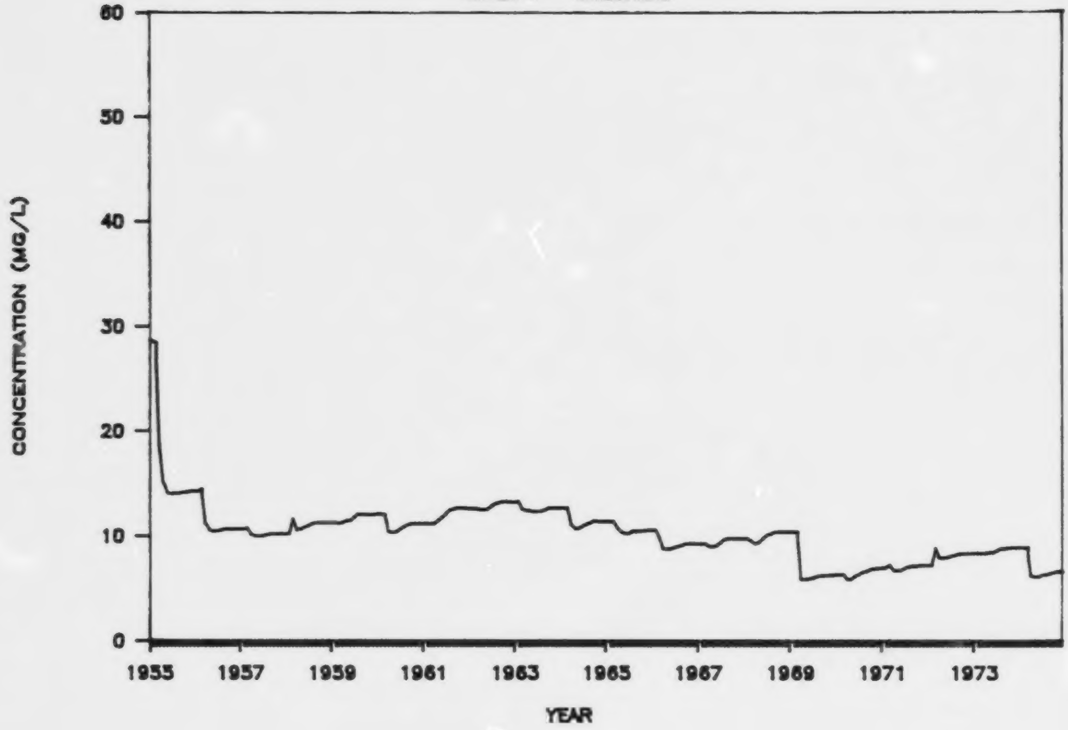
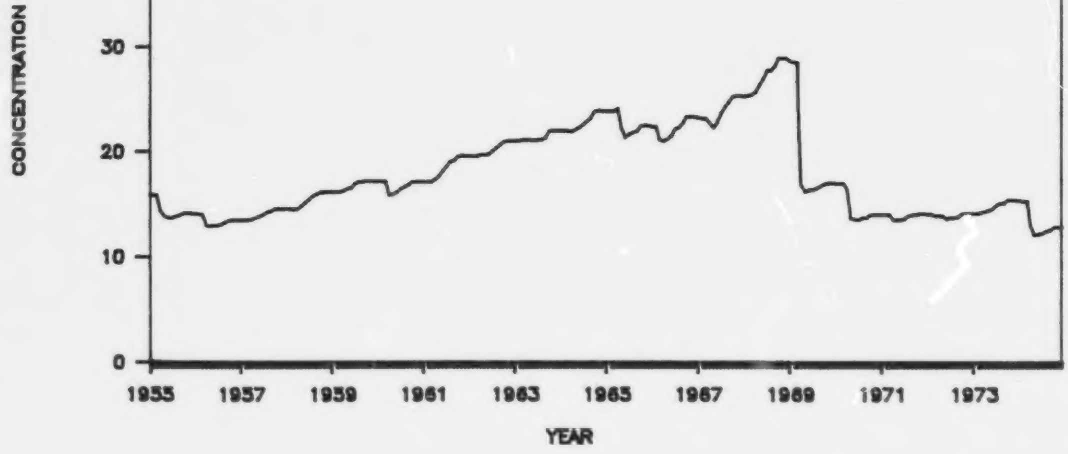

RAFFERTY RESERVOIR
SCEN 1 – SODIUM
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.12



ALAMEDA RESERVOIR

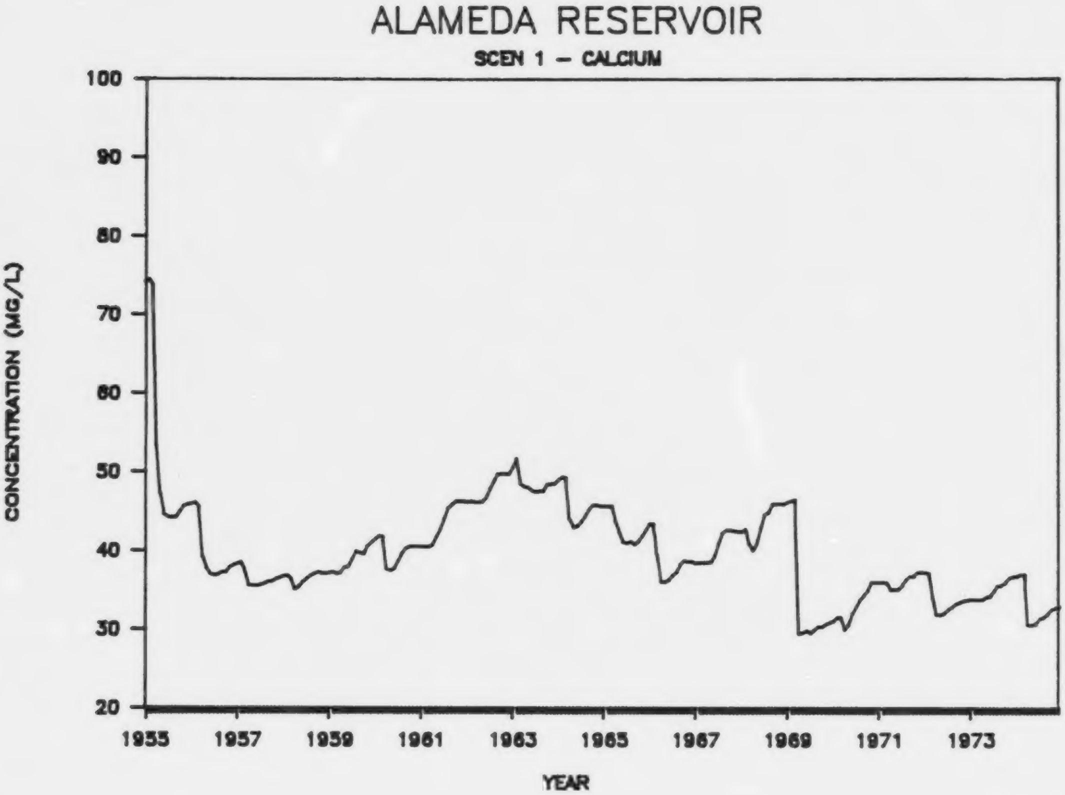
SCEN 1 – CHLORIDE



RAFFERTY RESERVOIR

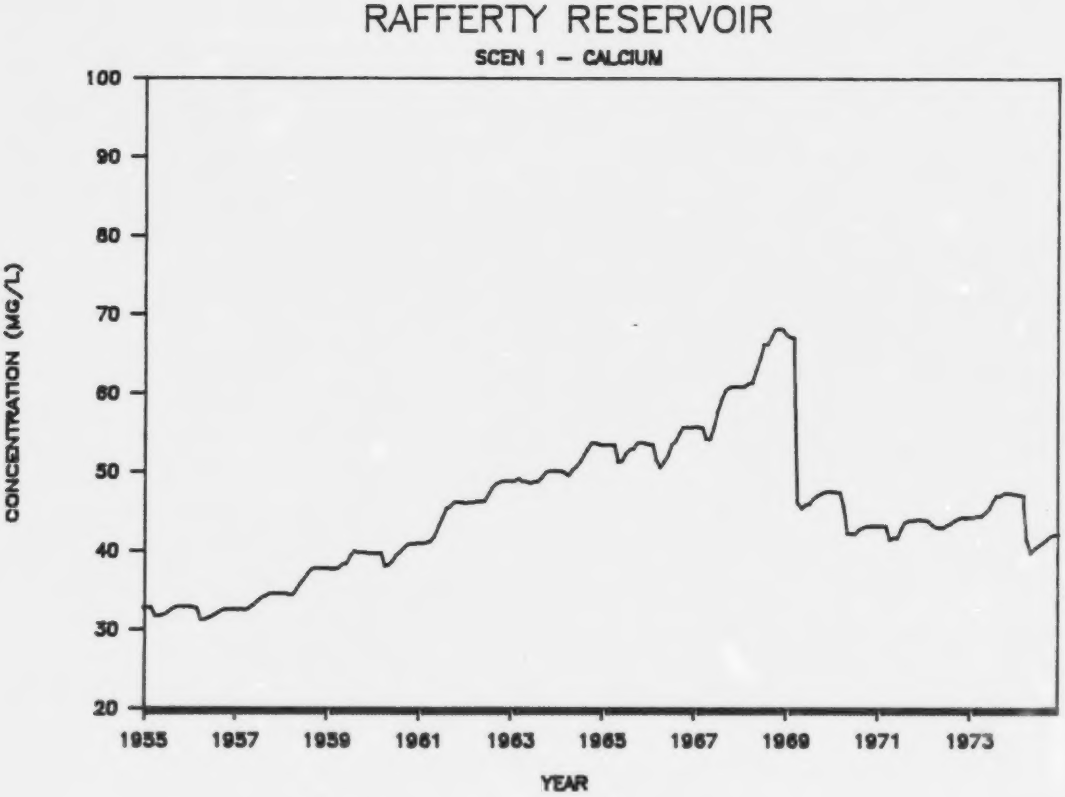
SCEN 1 – CHLORIDE

FIG. 3.13



ALAMEDA RESERVOIR

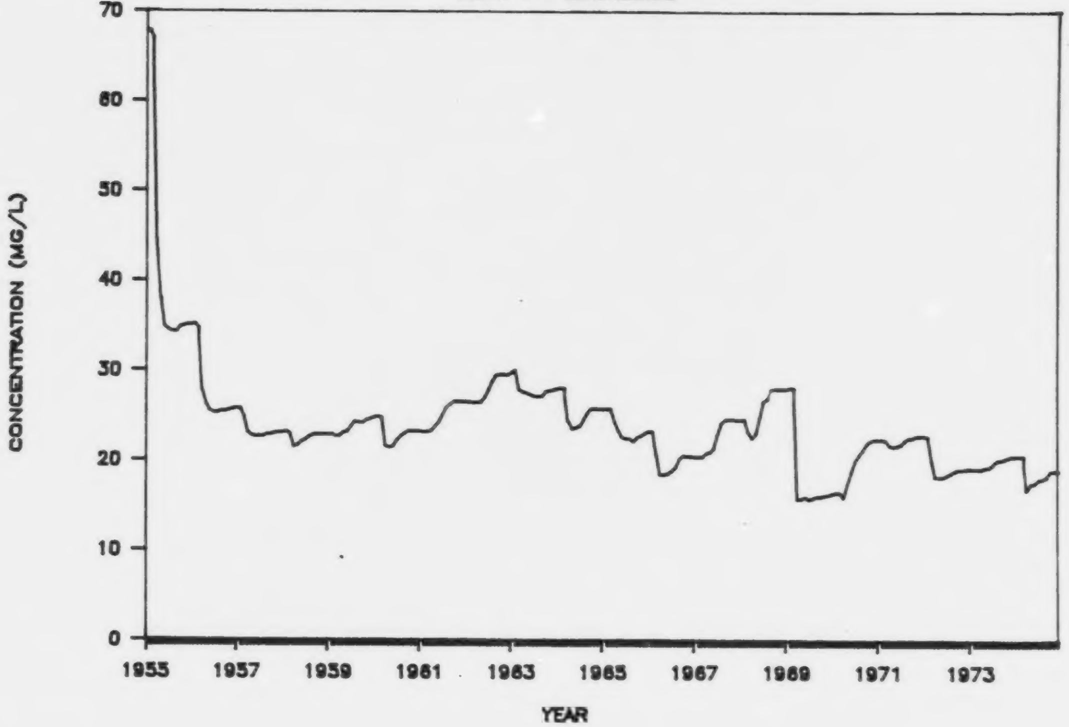
SCEN 1 — CALCIUM



RAFFERTY RESERVOIR

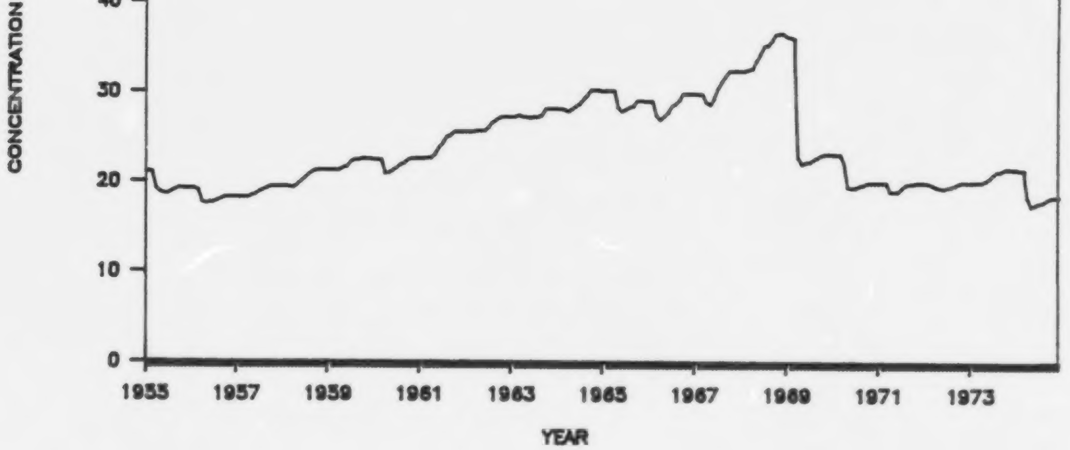
SCEN 1 — CALCIUM

FIG. 3.14



ALAMEDA RESERVOIR

SCEN 1 – MAGNESIUM



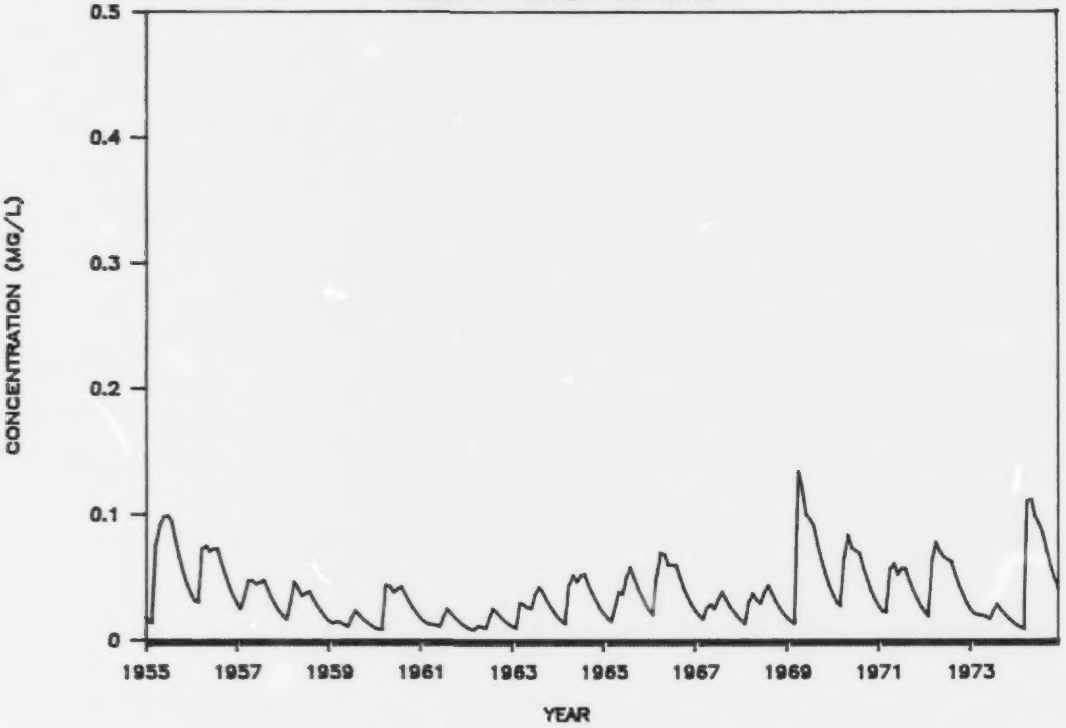
RAFFERTY RESERVOIR

SCEN 1 – MAGNESIUM

FIG. 3.15

ALAMEDA RESERVOIR

SCEN 1 – TOTAL PHOSPHORUS



RAFFERTY RESERVOIR

SCEN 1 – TOTAL PHOSPHORUS

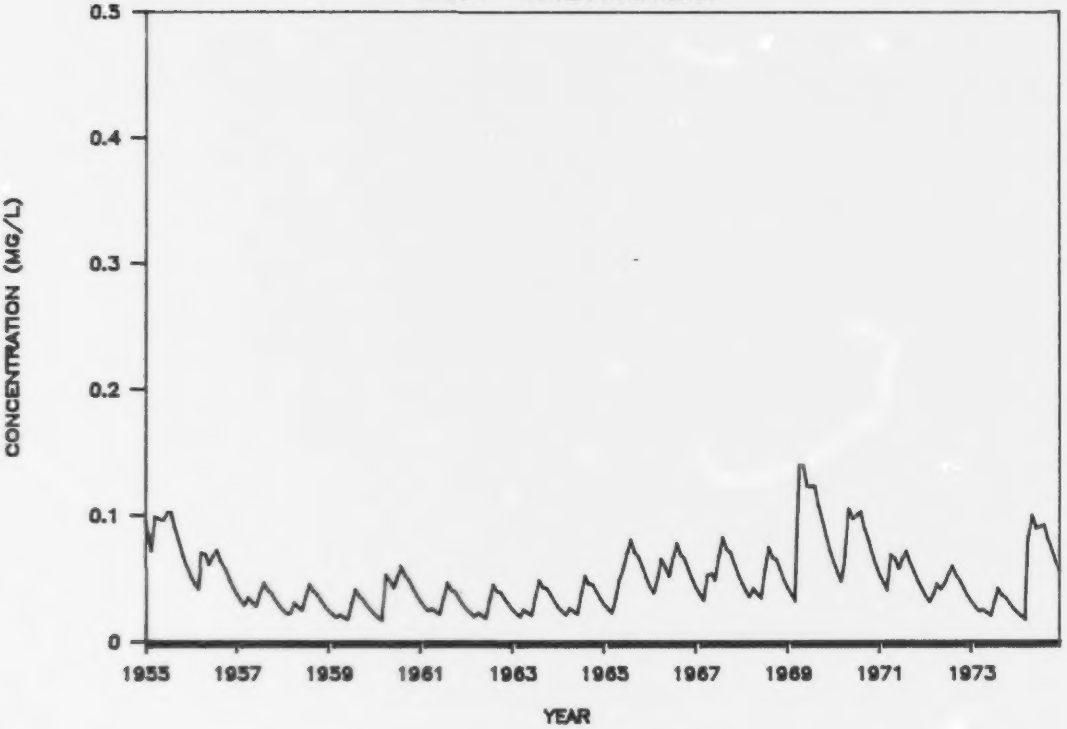
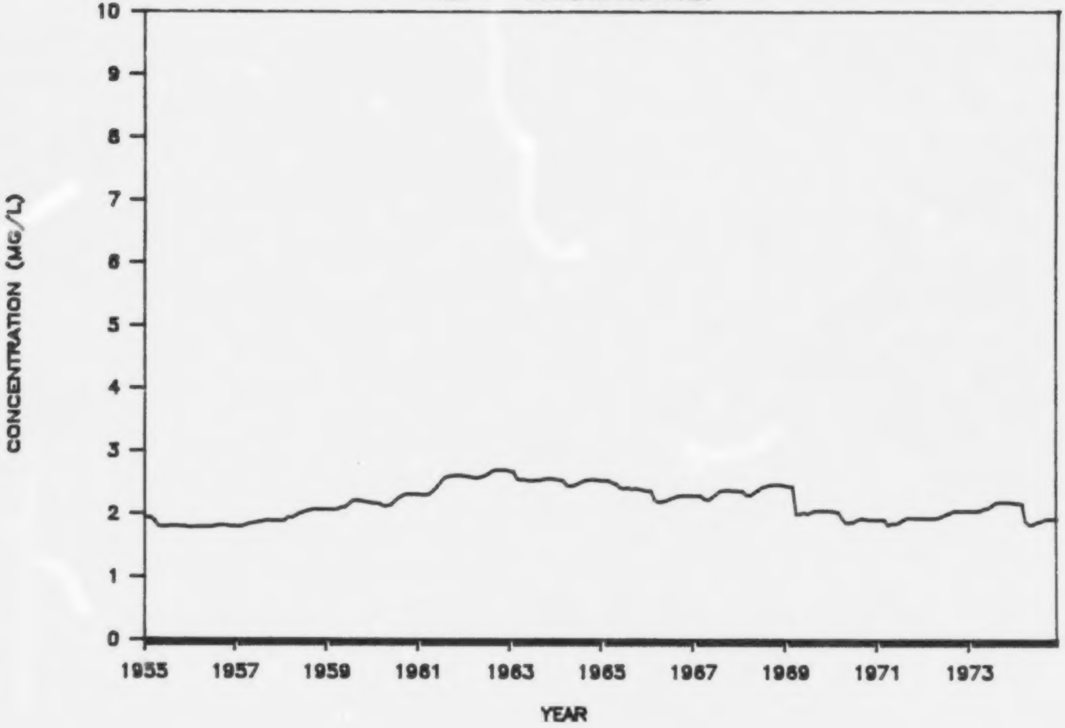


FIG. 3.16

ALAMEDA RESERVOIR

SCEN 1 – TOTAL K. NITROGEN



RAFFERTY RESERVOIR

SCEN 1 – TOTAL K. NITROGEN

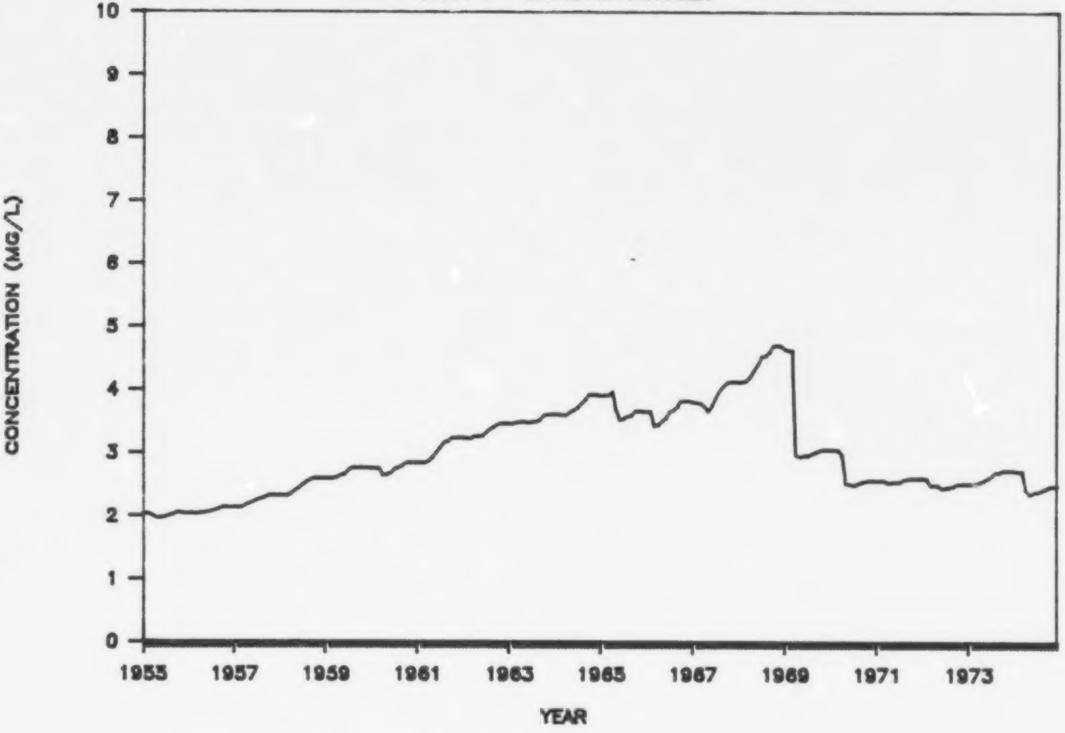
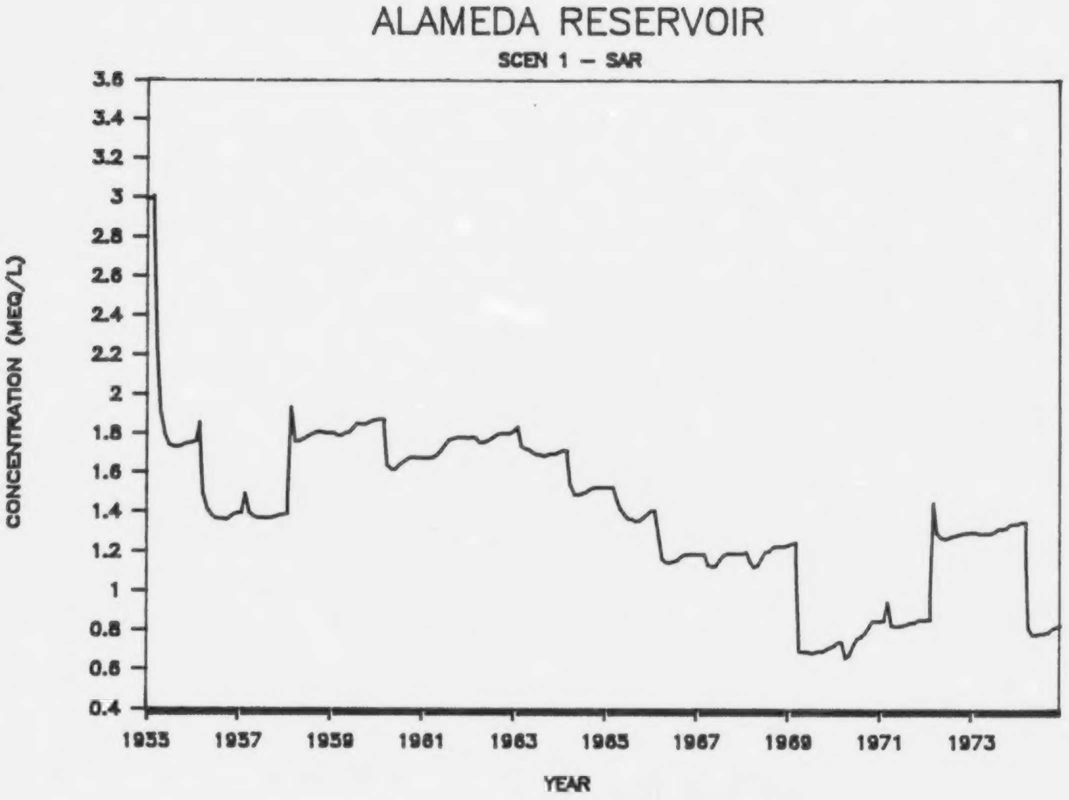
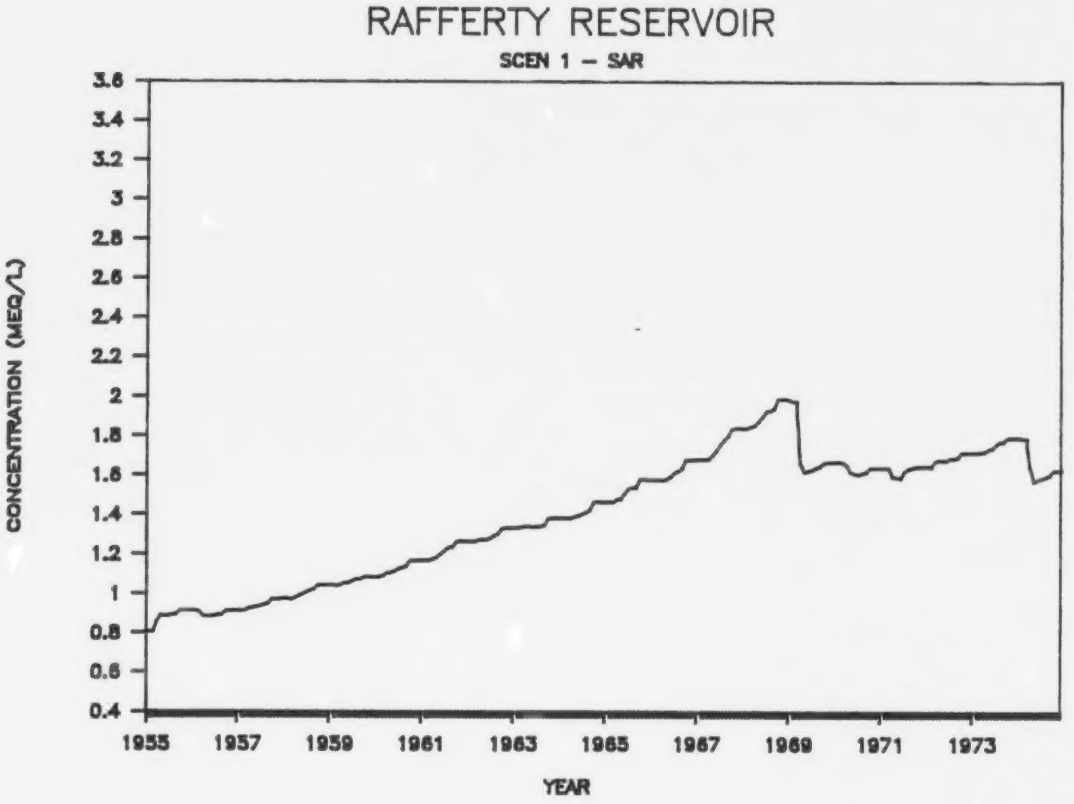


FIG.
3.17



ALAMEDA RESERVOIR

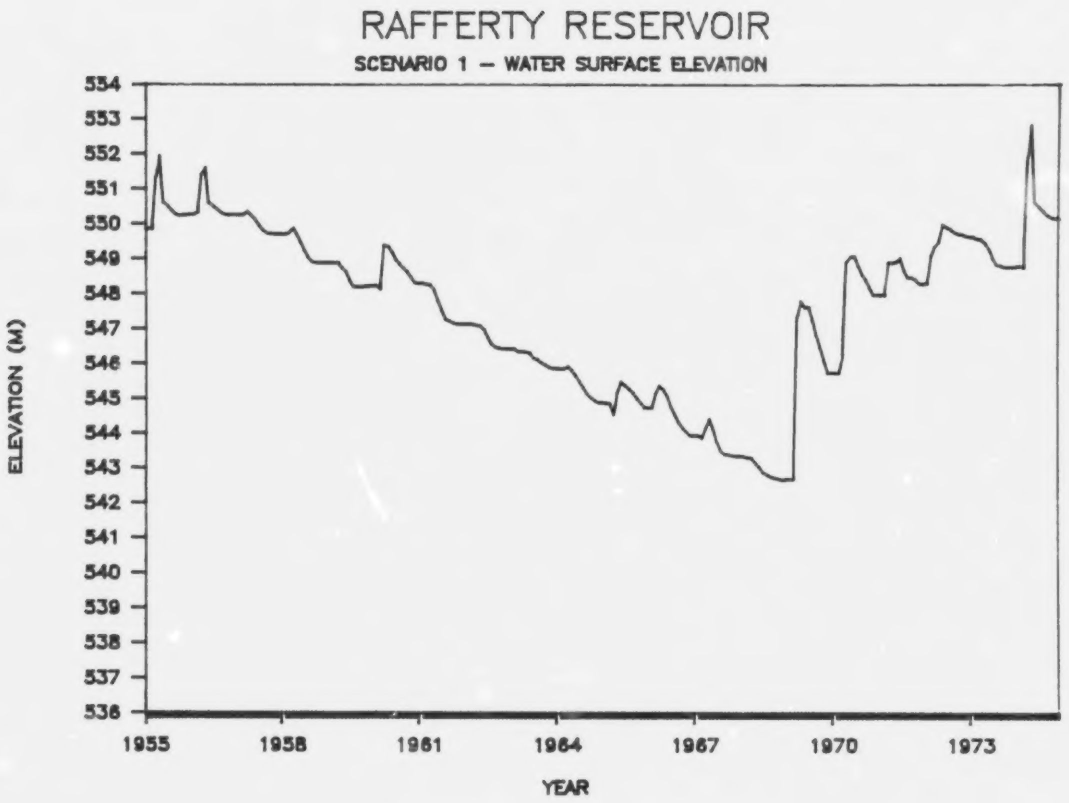
SCEN 1 – SAR



RAFFERTY RESERVOIR

SCEN 1 – SAR

FIG.
3.18


RAFFERTY RESERVOIR
SCENARIO 1 – WATER SURFACE ELEVATION
ELEVATION (M)
554
553
552
551
550
549
548
547
546
545
544
543
542
541
540
539
538
537
536
1955
1958
1961
1964
1967
1970
1973
YEAR

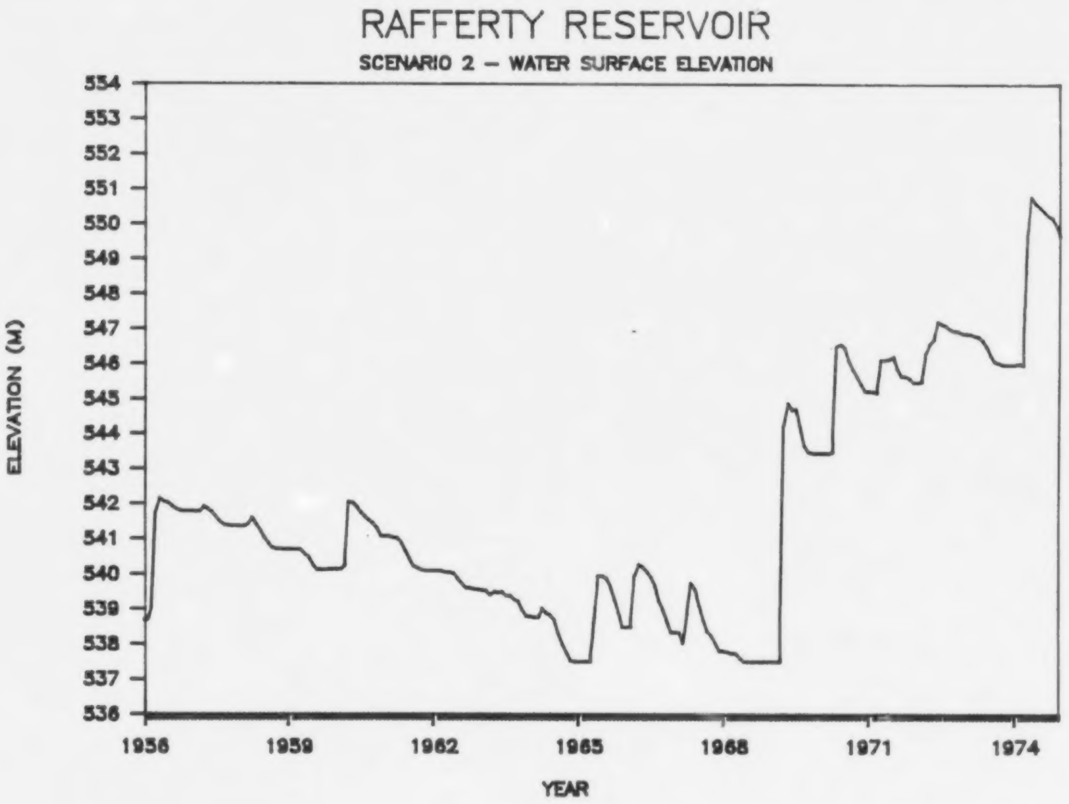
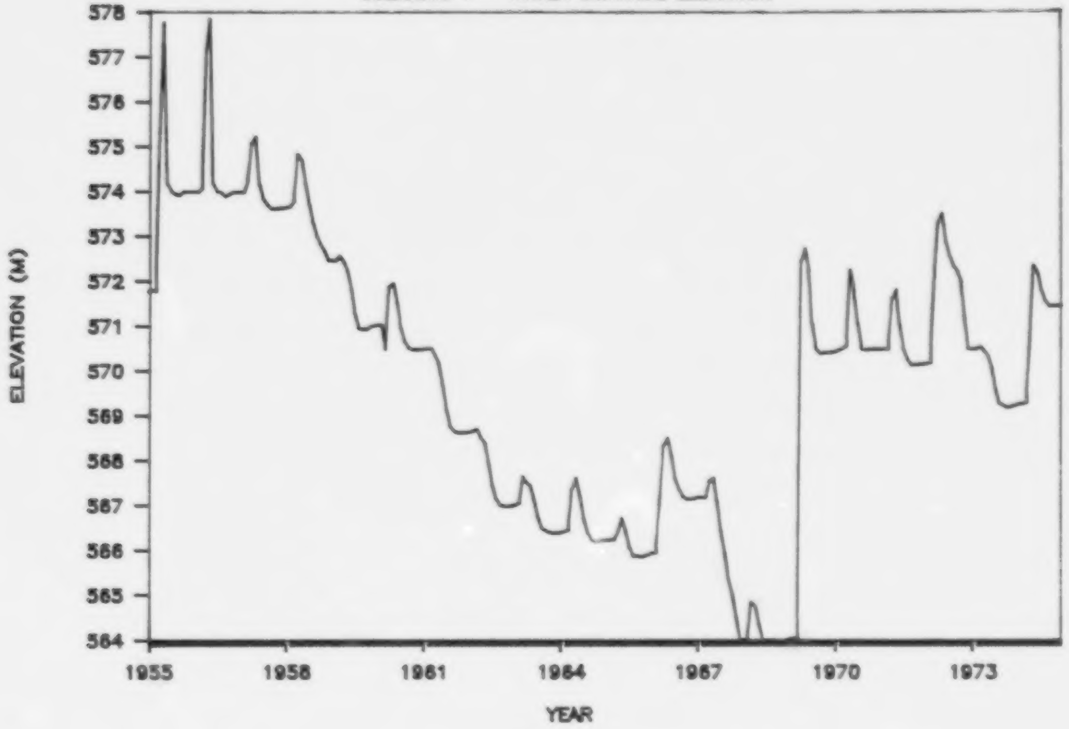

RAFFERTY RESERVOIR
SCENARIO 2 – WATER SURFACE ELEVATION
ELEVATION (M)
554
553
552
551
550
549
548
547
546
545
544
543
542
541
540
539
538
537
536
1956
1959
1962
1965
1968
1971
1974
YEAR

FIG.
3.19

ALAMEDA RESERVOIR

SCENARIO 1 — WATER SURFACE ELEVATION



ALAMEDA RESERVOIR

SCENARIO 2 — WATER SURFACE ELEVATION

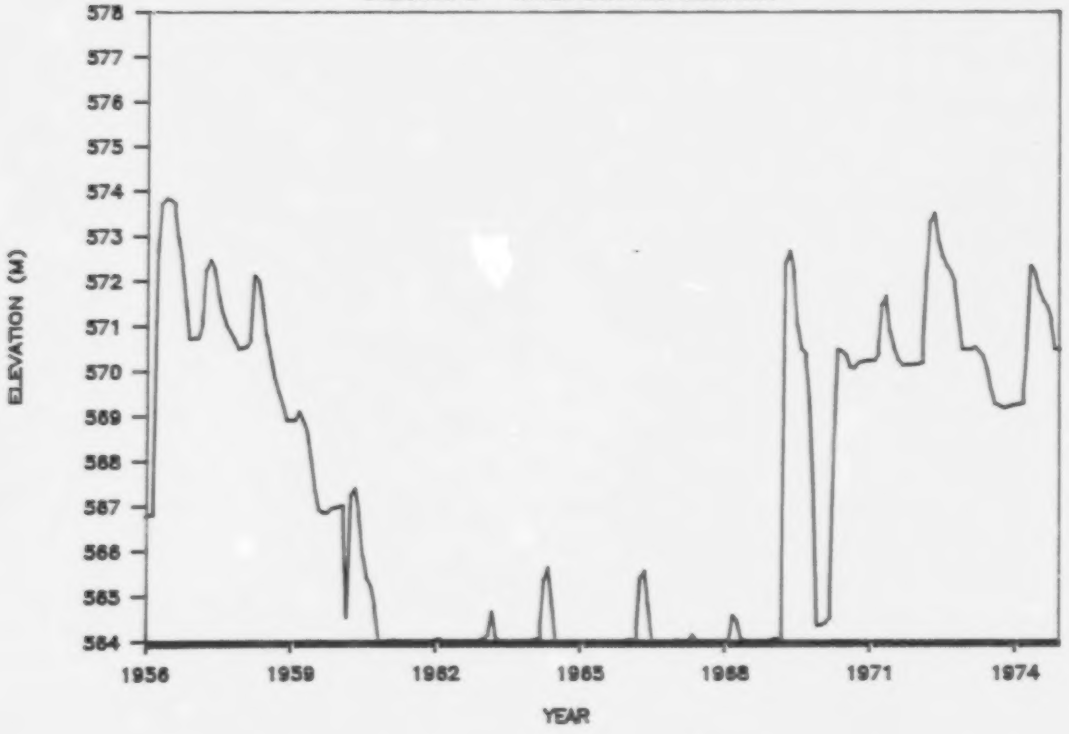


FIG.
3.20

The estimated long-term (1955 - 1974) patterns for calcium, sodium and chloride are similar to conductivity. Levels are generally lower in Alameda relative to Rafferty. Alameda experiences more year-to-year variability because of its shorter water residence time. Conversely the long-term patterns are more pronounced in Rafferty Reservoir. The effect of spill from Boundary Reservoir is apparent for some ions, i.e. Cl, Mg, during 1965, 1966, and 1967, but is not pronounced. In both reservoirs sodium adsorption ratios are forecast to remain below 2.0 (Figure 3.18)

Conductivity and the major ions were assumed to not undergo processing within the reservoir. In actuality, calcium may be lost due to precipitation. The reservoirs will be biologically productive and as such the free carbon dioxide will be depleted during summer months. This will probably result in high pH levels (8.5 to 9.5) and precipitation of calcium carbonate (Petts 1984, Schwartzkopf & Hergenroder 1978).

Total phosphorus is often the primary nutrient controlling aquatic plant and algal production and therefore is generally considered to be the main determinant of trophic status. Average phosphorus concentrations are predicted to be higher in Rafferty Reservoir relative to Alameda (Table 3.6, Figure 3.16), however, in both instances the predicted values fall within the eutrophic range. Year-to-year variability is considerable for both reservoirs. In some years mesotrophic levels of TP are approached.

Table 3.6 Trophic state analysis.

Predicted Reservoir Conditions

	RAFFERTY	ALAMEDA
TP (mg/l)	0.049	0.038
Average Chlorophyll[1] (mg/m^3)	19 (13)[2]	14 (10)[2]
Maximum Chlorophyll[2] (mg/m^3)	37	28

Trophic Classification[3]

	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC
TP (mg/l)	<0.010	0.010-0.020	>0.020
Average Chlorophyll (mg/m^3)	<4	4-10	>10
Secchi depth (m)	>4	2-4	<2

---

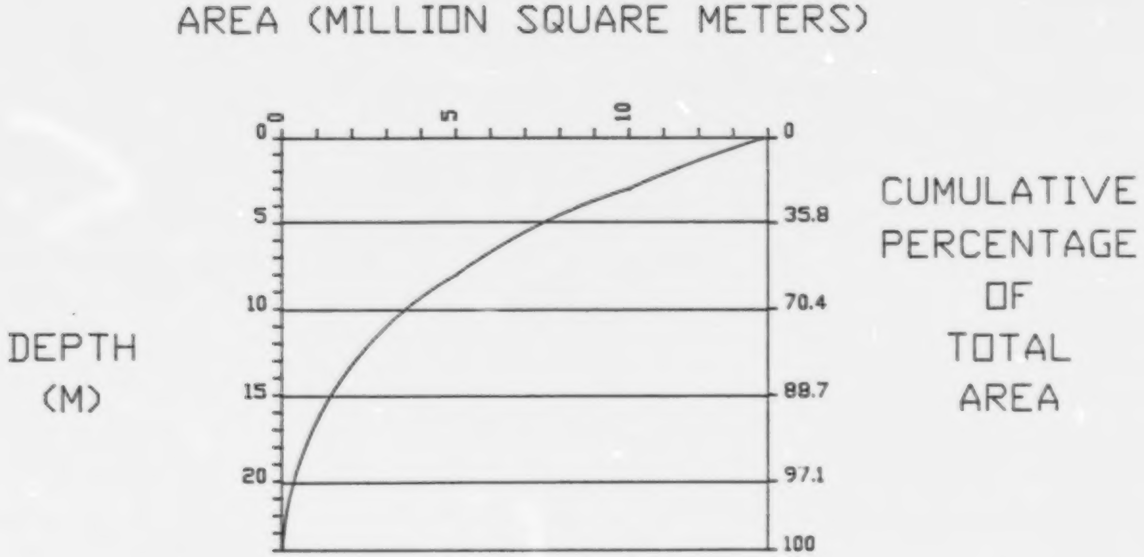
1 Prepas & Trew 1983
2 Vollenweider & Kerekes 1981
3 Mancini 1983

In both reservoirs phosphorus concentrations are greatest during spring runoff, in March and April. Concentrations then decline in May and June due to settling. In July and August a net release of phosphorus from the sediments was predicted. Recent studies have shown shallow productive prairie lakes and reservoirs usually experience internal loading during the summer growing season (Riley & Prepas 1984, Reynoldson & Hamilton 1982, Mitchell 1984). A nutrient loading of the Qu'Appelle system Fishing Lakes, which had been subject to high phosphorus loadings, determined a net export of 43.19 tonnes of P (32% of inflow mass) over the 1980-83 period.(Munro 1986) Considering that the predominant form of phosphorus changed from particulate at the inflow to dissolved (primarily ortho) at the outlet, Munro (1986) speculated that regeneration from lake sediments was largely responsible for the increase. This internal loading is reduced in systems which thermally stratify, thereby limiting the exchange between hypolimnetic (bottom) and epilimnetic (surface) waters. Rafferty and Alameda are both relatively shallow even at full FSL (Figures 3.21 and 3.22.)

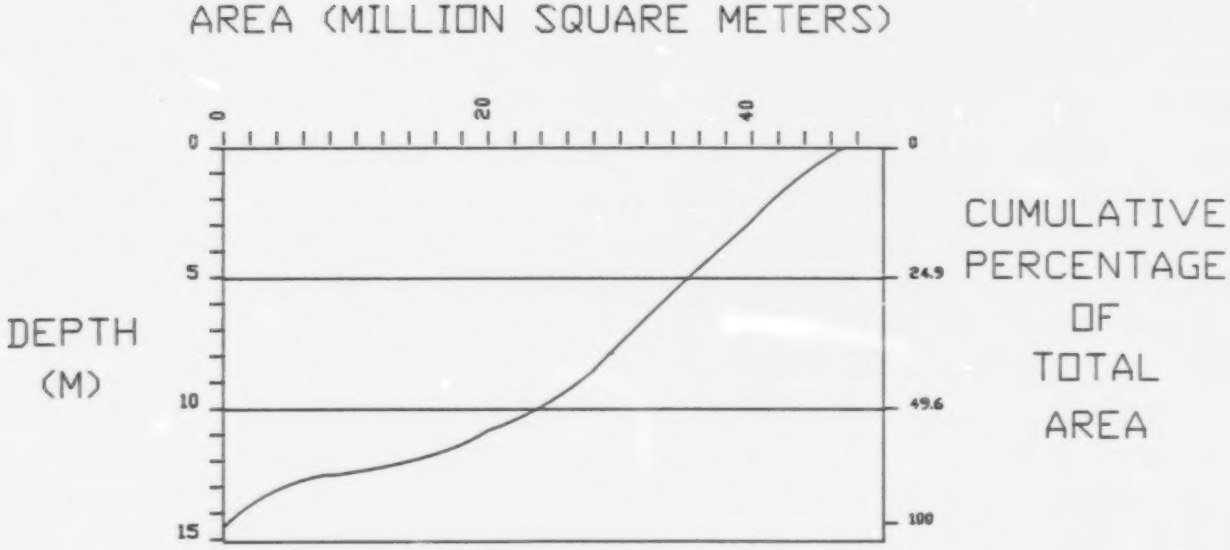
In prairie systems, permanent thermal stratification usually only occurs when a substantial volume of the reservoir occurs at depths deeper than 10 m. In shallow systems, like Rafferty and Alameda, internal phosphorus loads can result from direct wind induced mixing of bottom sediments into the water column, or from circulation of nutrient rich bottom waters following periods of intermittent stratification. At FSL, Rafferty will have a significant 10 to 13 m depth zone. This depth is ideally suited for intermittent stratification, and therefore favors high internal loadings (Riley & Prepas 1985).

In addition to morphometry, the rate of internal phosphorus loading is related to sediment type (Mawson et al. 1983). It is minimal for sand, moderate for refractory organic silt and high for heavy organic muck. A low to moderate rate of internal loading was assumed for Rafferty and Alameda because substrate conditions will be much less organic than values for naturally occurring lake systems.

Empirical relationships based upon average total phosphorus concentrations can be used to predict average and maximum chlorophyll levels (Table 3.6). Chlorophyll is a measure of algal biomass. Predicted values are high (in the eutrophic range) for both reservoirs, however, again algal densities should be greatest in Rafferty. Average chlorophyll, based upon the Prepas and Trew (1983) relationship, is higher than that predicted by Vollenweider & Kerekes (1981). The Prepas & Trew estimates may be more reliable because they are regionally specific,



ALAMEDA FIG. 3.21



RAFFERTY RESERVOIR FIG. 3.22

whereas the Vollenweider model was developed with data collected from throughout North America and Europe.

Prairie reservoirs and lakes are often very productive (Barica 1977, Mercil et al. 1979, Schwartzkopf & Hergenroder 1978). Seasonally, algal populations are often dominated by diatoms in early spring, followed by blue-green algae in mid to late summer. These latter groups can develop aesthetically unpleasant blooms that could impair recreational use, and in extreme cases cause oxygen depletion and summerkill of fish (Barica 1975).

Total kjeldahl nitrogen is a measure of organic nitrogen plus ammonia (Table 3.5, Figure 3.17). It does not include nitrate and nitrite. Like phosphorus, nitrogen is also an aquatic plant nutrient, but usually does not regulate ultimate plant or algal density. The predicted total nitrogen values for Rafferty and Alameda Reservoirs are based upon a simple mass balance. The values do not consider sediment interactions or internal fixation of atmospheric nitrogen by blue-green algae.

TKN levels in Alameda are forecast to remain relatively stable through time, whereas levels in Rafferty Reservoir will be affected by the low relative flushing rate and high evaporation. Because of the high phosphorus levels, and its eutrophic condition Rafferty will likely experience significant blue-green algal blooms and associated nitrogen fixation. This may increase TKN concentrations above levels presently simulated.

The nitrogen cycle in productive prairie lakes in southern Manitoba has been documented by Barica (1974, 1977). His findings indicate nitrates usually remain low year round. Ammonia levels increase significantly during winter, especially if de-oxygenation is complete, or nearly so. During spring, biological uptake converts ammonia to organic nitrogen. Ammonia levels can subsequently increase at irregular intervals over the summer growing season in response to algal bloom decay.

Of the total kjeldahl nitrogen, a portion will be present in the ammonia form. With increasing temperatures and pH, the percentage of un-ionized ammonia, which is potentially toxic to fish, also increases. Based on data from Boundary Reservoir and its outflow, the spring through fall ammonia percentages averaged from approximately 5 to 16. Using the high values and a water column temperature of 17° and pH of 8.5, the potential un-ionized ammonia levels in Rafferty could approach 0.05 mg/L. While this concentration would rapidly diminish with decreasing temperatures, periodic high values could occur, particularly in localized areas.

For most of the water column, summer dissolved oxygen levels in Rafferty and Alameda reservoirs should fluctuate around the 100% saturation level. Because the reservoirs are productive, photosynthesis and respiration will cause oxygen levels to vary diurnally. During day light hours oxygen production due to photosynthesis will increase levels above saturation. At night, when photosynthesis stops, continued biological respiration will consume oxygen and cause levels to drop below saturation. At no time should surface oxygen concentrations reach critical levels.

Due to their shallow depth, the reservoirs should not permanently stratify, therefore, significant hypolimnetic oxygen depletion will not occur. However, at FSL Rafferty reservoir may stratify intermittently. During these periods bottom water oxygen levels may decline to low levels. These oxygen deficits should be replenished when the lakes circulate again in response to wind activity.

During winter, when atmospheric reaeration is limited by ice cover, oxygen depletion in prairie lakes and reservoirs can be severe. Complete de-oxygenation can result in winterkill of any fishery. Two empirical models were used to predict probable winter oxygen levels in Rafferty & Alameda reservoirs at FSL, and at the lowest water level predicted the 1955 - 1974 simulation period (Tables 3.7, 3.8). One model was developed for productive pothole lakes in southern Manitoba (Barica & Mathias 1979), while the other is based upon data for parkland lakes in central Alberta (Babin & Prepas 1985). In both instances ice cover was assumed to commence December 1, and at that time reservoir oxygen levels would be near saturation 13 mg/l (assuming 4°C).

Table 3.7 Predicted reservoir oxygen conditions using depletion rate model for lakes in southern Manitoba (Barica and Mathias 1979).

	ALAMEDA		RAFFERTY	
	FSL	MIN	FSL	MIN
Mean Depth elevation (1955 - 1974) (m)	7.5	5.2	8.9	4.4
Predicted O_2 depletion rate (g/m² /day)	0.61	0.46	0.67	0.42
Predicted O_2 (mg/l)				
December 1	13.0	13.0	13.0	13.0
January 1	10.5	10.2	10.6	10.0
February 1	8.0	7.4	8.1	7.1
March 1	5.7	4.9	5.9	4.4

Table 3.8 Predicted reservoir oxygen conditions using depletion rate model for lakes in central Alberta (Babin & Prepas 1985).

	ALAMEDA		RAFFERTY	
	FSL	MIN	FSL	MIN
Mean Depth (1955 - 1974) (m)	7.5	5.2	8.9	4.4
Predicted O_2 depletion rate (g/m² /day)	0.47	0.39	0.52	0.36
Predicted O_2 (mg/l)				
December 1	13.0	13.0	13.0	13.0
January 1	11.1	10.7	11.2	10.5
February 1	9.1	8.4	9.4	7.9
March 1	7.4	6.3	7.7	5.6

Both models predict the average March 1 oxygen level in Alameda reservoir will remain above 5.0 mg/l at both FSL and the predicted low water level. In Rafferty Reservoir, winter oxygen levels should also remain at adequate levels.

In both instances, a linear depletion rate was assumed from levels near saturation. In actuality the depletion rate is usually more rapid in the early winter and decreases somewhat in late season (Babin & Prepas 1985). Also, in March algal growth can commence before the ice melts, and the resulting photosynthesis can, to some extent, replenish low oxygen levels. This factor is dependent upon relative ice thickness and snow cover. The oxygen content of the reservoirs at freeze-up is a key variable determining the overall winter oxygen condition. In this analysis, fall circulation was assumed to result in levels near saturation. If this does not occur the winter condition will be worsened.

A review of available Saskatchewan Environment winter dissolved oxygen vertical profile data for Katepwa, Crooked, and Round Lakes in the Qu'Appelle River system over the 1976 - 1982 period suggests highly variable depletion rates both by year and by lake location. Using recorded freeze-up dates and assumed freeze-up saturation levels, the estimated rates were calculated and are summarized in Table 3.9.

Table 3.9 - Estimated Winter Dissolved Oxygen Depletion Rates
Qu'Appelle River System Lakes

	Profile Sites	Depths, m	Time, days	Depletion Rates($g/m^2/d$)	
				Range	Average
Katepwa Lake	3	18.2-19.5	84	0.77 - 1.16	0.92
	4	21	65	-0.77 - -0.45	-0.63
	4	19.8-20	56	0.04 - 0.36	0.20
	4	18.5-19.0	42	-1.013 - 0.14	-0.42
Crooked Lake	3	10.8-14.0	54	1.13 - 2.10	1.64
	3	9.0 - 14.0	96	0.21 - 0.58	0.45
	3	10.0-14.5	89	0.43 - 1.08	0.65
	3	8.2-14.0	60	0.08 - 0.82	0.47
Round Lake	2	9.5-10.0	63	1.65 - 1.77	1.71
	2	9.2-10.7	105	0.23 - 0.44	0.34
	2	11.3-13.1	94	0.02 - 0.23	0.12
	2	10.5-11.0	114	0.55 - 0.61	0.58

3.2.2 Downstream River Conditions

Water quality of the Souris River is naturally variable. During spring and early summer, snowmelt and spring rains result in yearly maximum streamflows. In those seasons total salinity and major ion concentrations are reduced due to surface runoff contributing the majority of river flow (Figures 3.4 to 3.10). Alternatively, nutrient and suspended solid levels can increase at that time. During late summer, fall and winter flows decrease as runoff is depleted, and groundwater inflows increase in importance. This causes major ion concentrations to increase and a reduction in nutrient levels.

With construction of Alameda and Rafferty Reservoirs, the spring peak flows will be reduced and summer flows increased (Figures 3.23 and 3.24). At the same time reservoir storage will dampen much of the normal seasonal variability in river concentrations. Figures 3.25 to 3.31 present simulated river concentrations for the Souris River at Glen Ewen after reservoir construction. These results are directly comparable to calibration Figures 3.4 to 3.9, which represent the historical condition. Observed monthly average monitoring data are also included on the plots.

For conductivity and major ions, river concentrations will be decreased during June, July and August. This results from the change in flow regime, and the relatively good quality source water in the two reservoirs. Late fall and winter ion concentrations will be reduced marginally as diffuse source inflows still form a significant proportion of the flow during these seasons. Spring conditions will be largely unaltered.

Nutrient concentrations in the Souris River should be improved by basin regulation. Levels are currently high due to normal runoff from agricultural lands. The reservoirs will provide a net retention of phosphorus, which in turn improves downstream water quality.

The simulated results discussed above are based upon a simple mass balance for major ions and nitrogen. Phosphorus in turn is affected by sedimentation and sediment release. Other unaccounted effects that could alter what is projected here include:

- depletion of dissolved nutrients from the Souris due to biological uptake in the reservoirs.
- potential effects on downstream water quality due to bottom release of de-oxygenated waters during periods of intermittent stratification.
- some reduction of calcium carbonate due to precipitation in the reservoir.

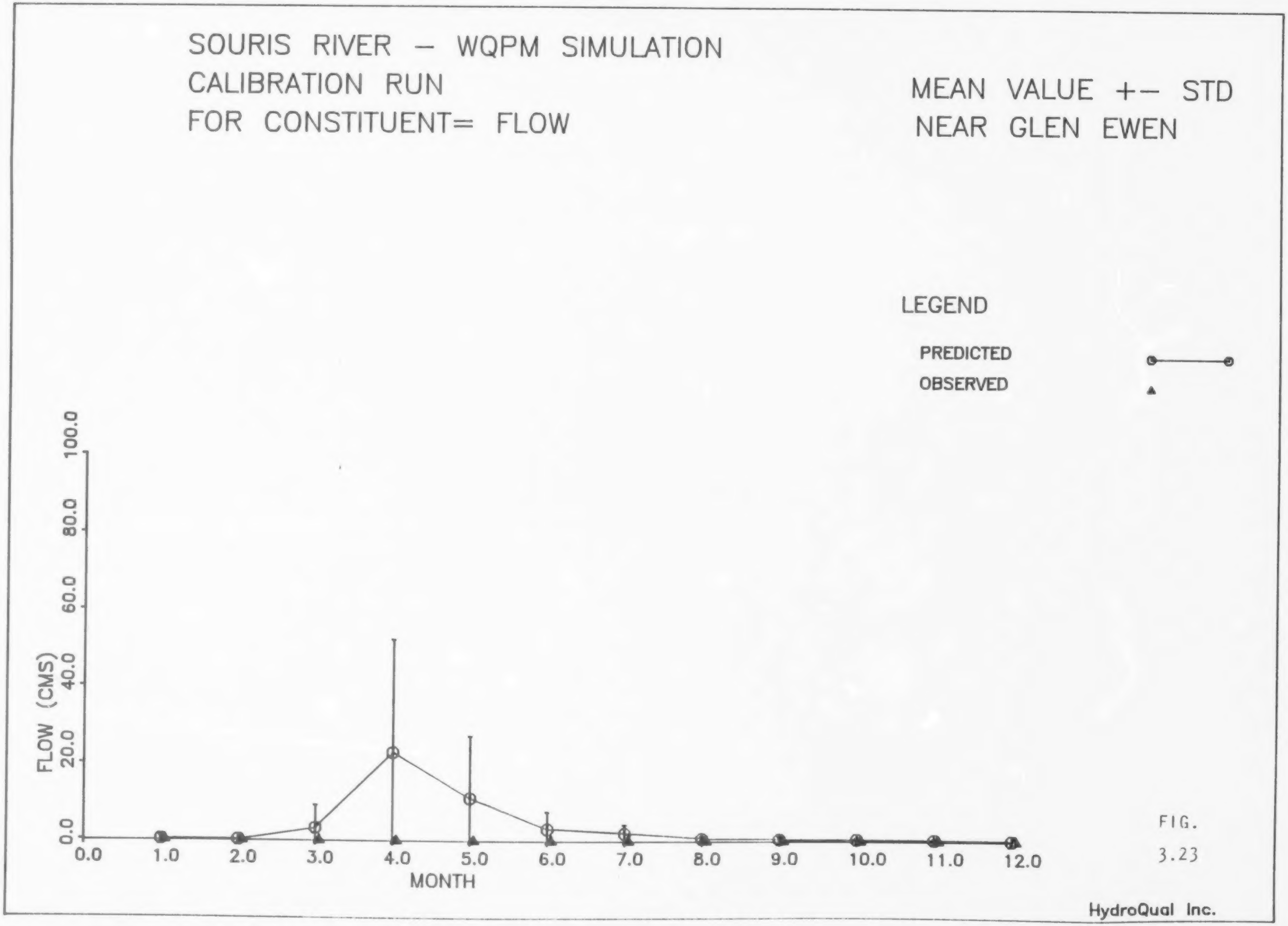

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= FLOW
MEAN VALUE +– STD
NEAR GLEN EWEN
LEGEND
PREDICTED
OBSERVED
FLOW (CMS)
0.0
20.0
40.0
60.0
80.0
100.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
MONTH
HydroQual Inc.

FIG. 3.23

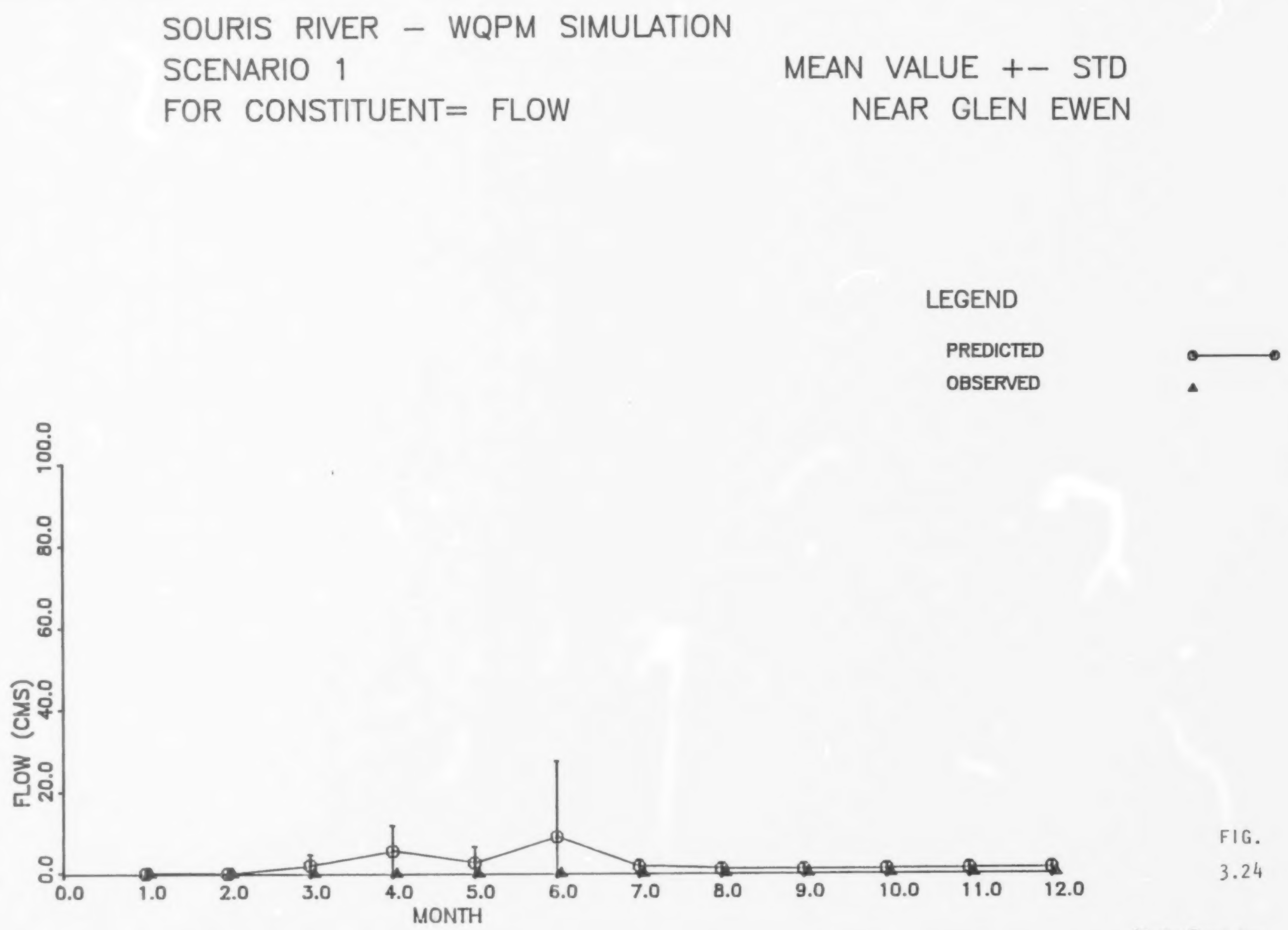


FIG. 3.24

HydroQual Inc.

SOURIS RIVER – WQPM SIMULATION
SCENARIO 1
FOR CONSTITUENT= CONDUCTIVITY

MEAN VALUE +– STD
NEAR GLEN EWEN

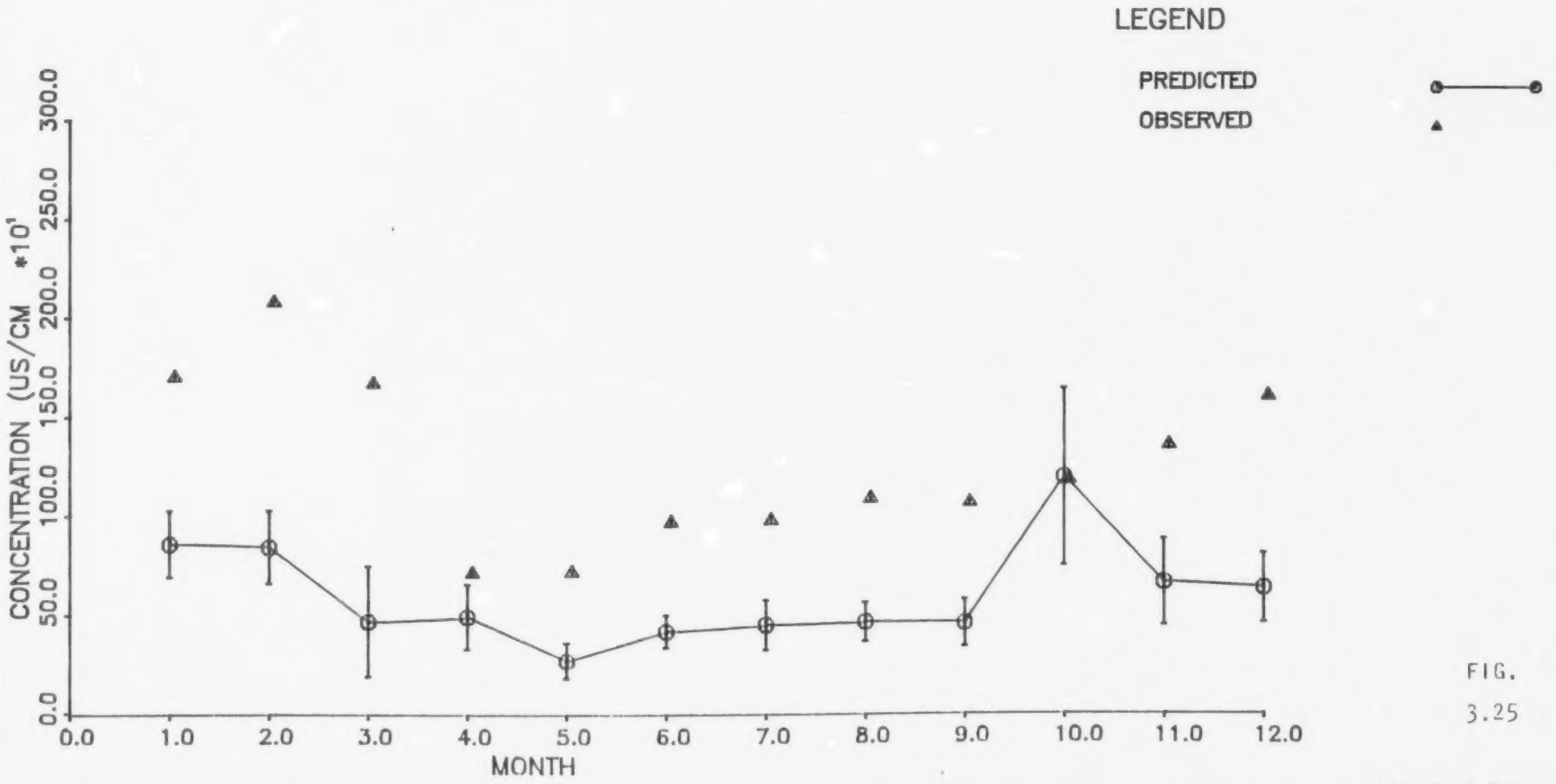


FIG. 3.25

HydroQual Inc.

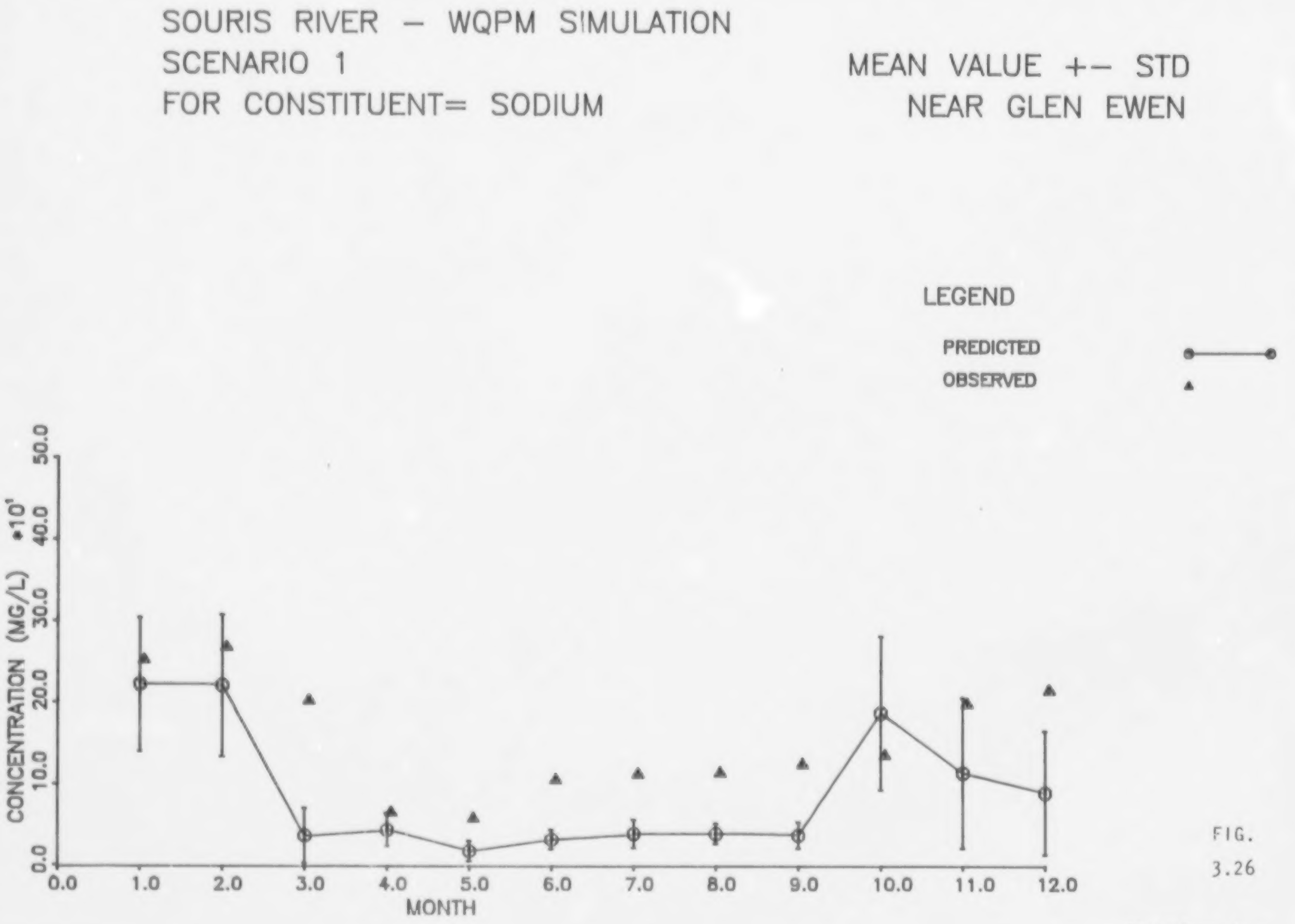


FIG. 3.26

HydroQual Inc.

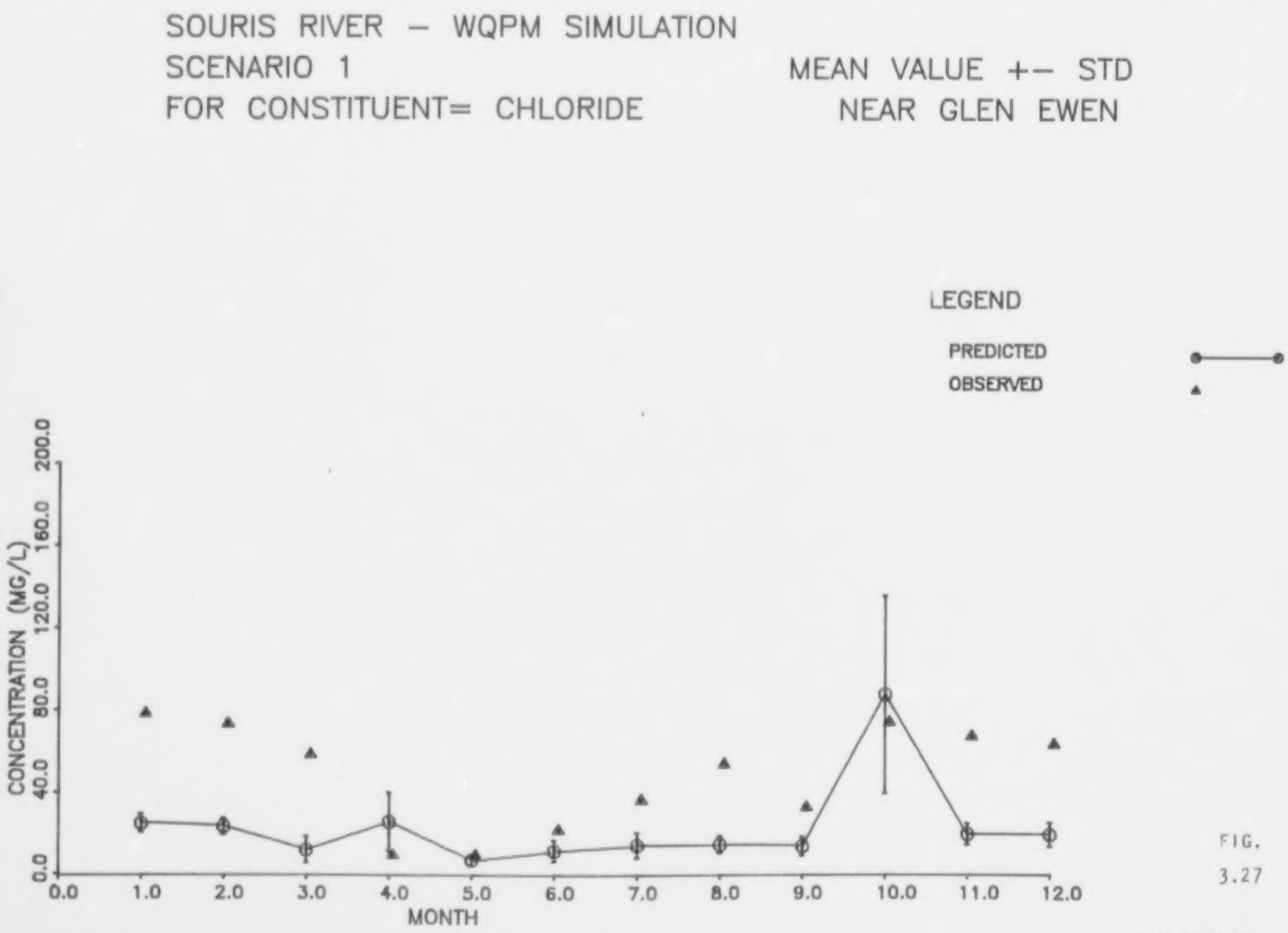


FIG. 3.27

HydroQual Inc.

SOURIS RIVER – WQPM SIMULATION
SCENARIO 1
FOR CONSTITUENT= CALCIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

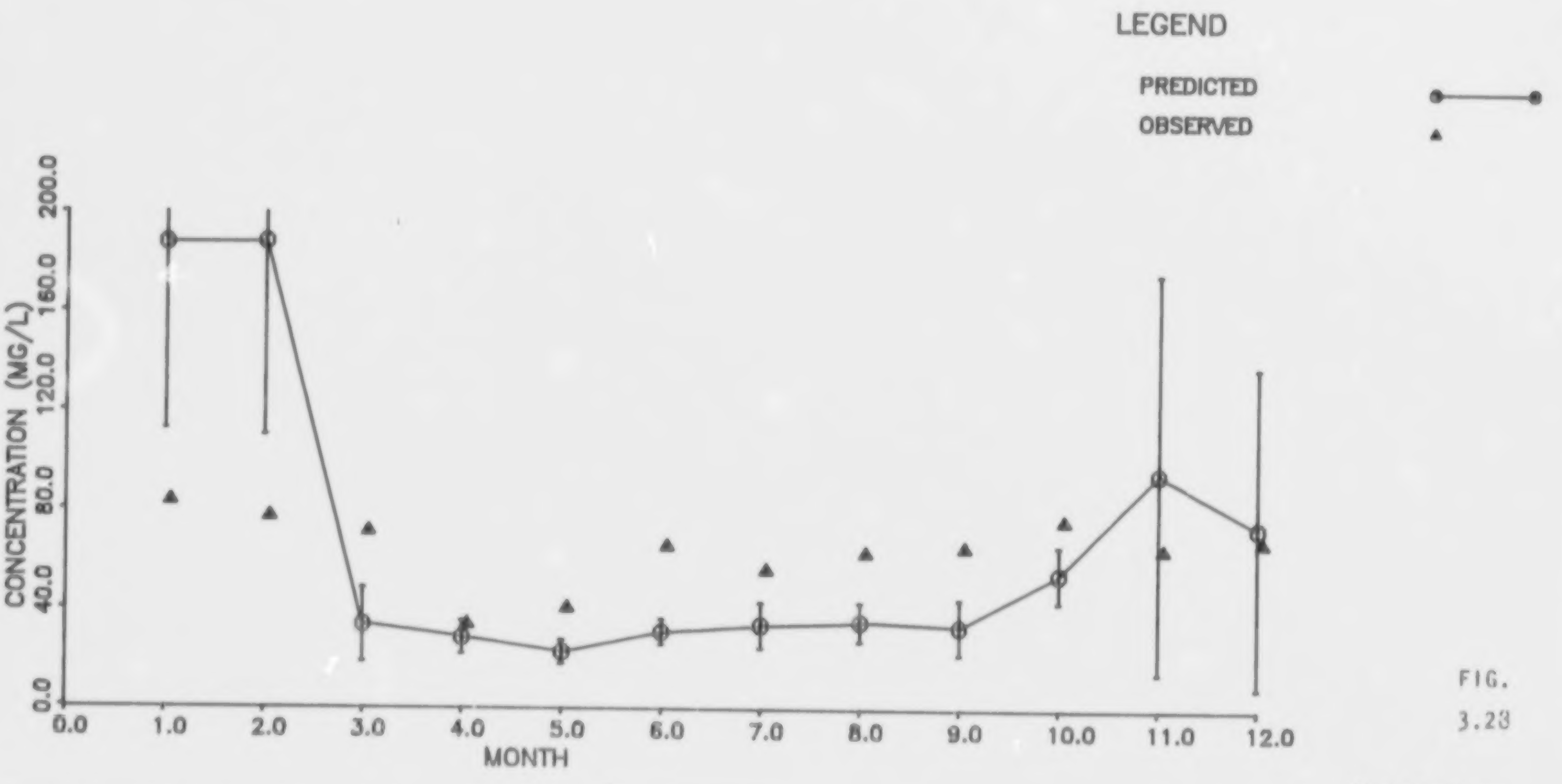


FIG. 3.23

HydroQual Inc.

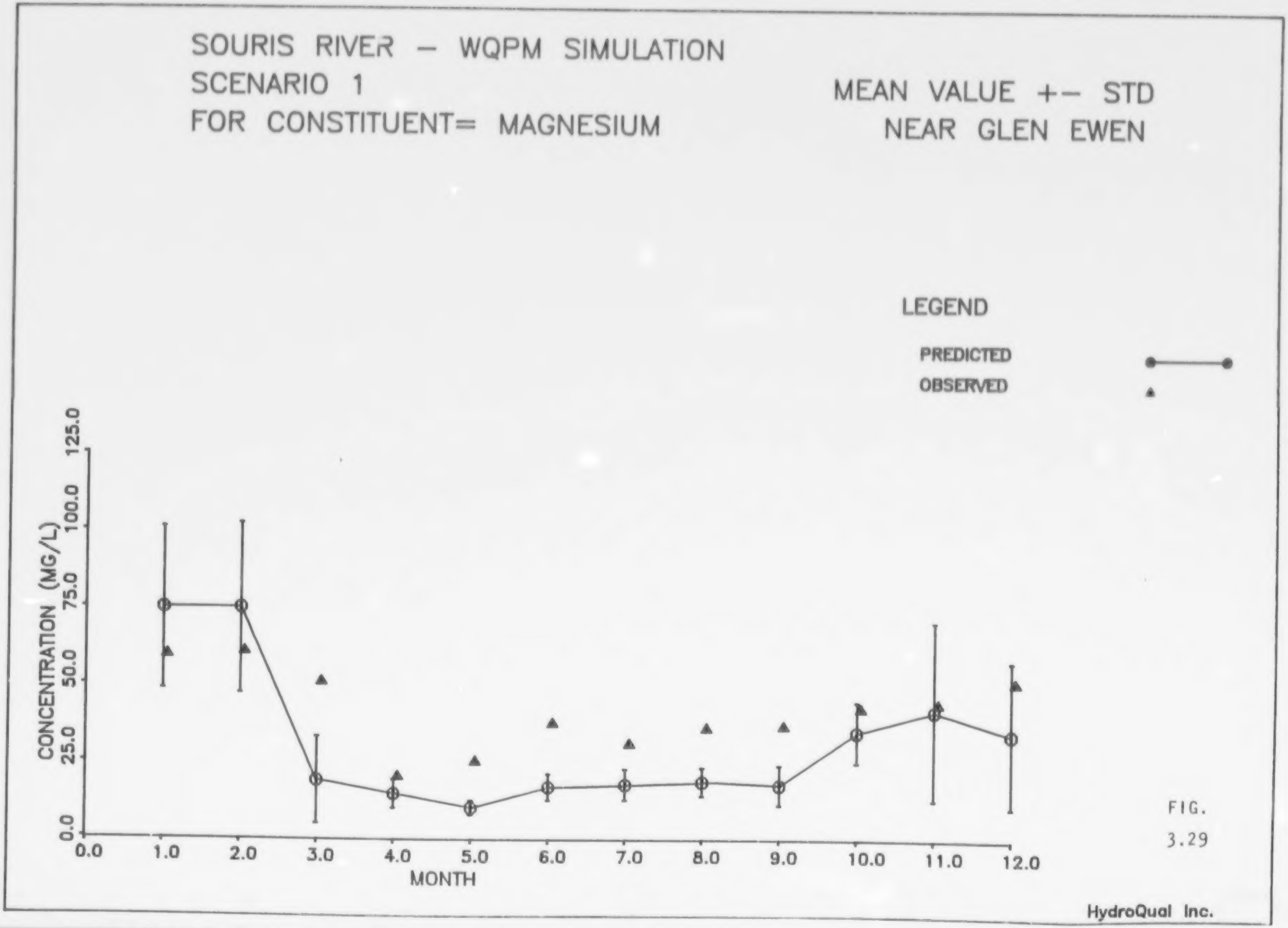
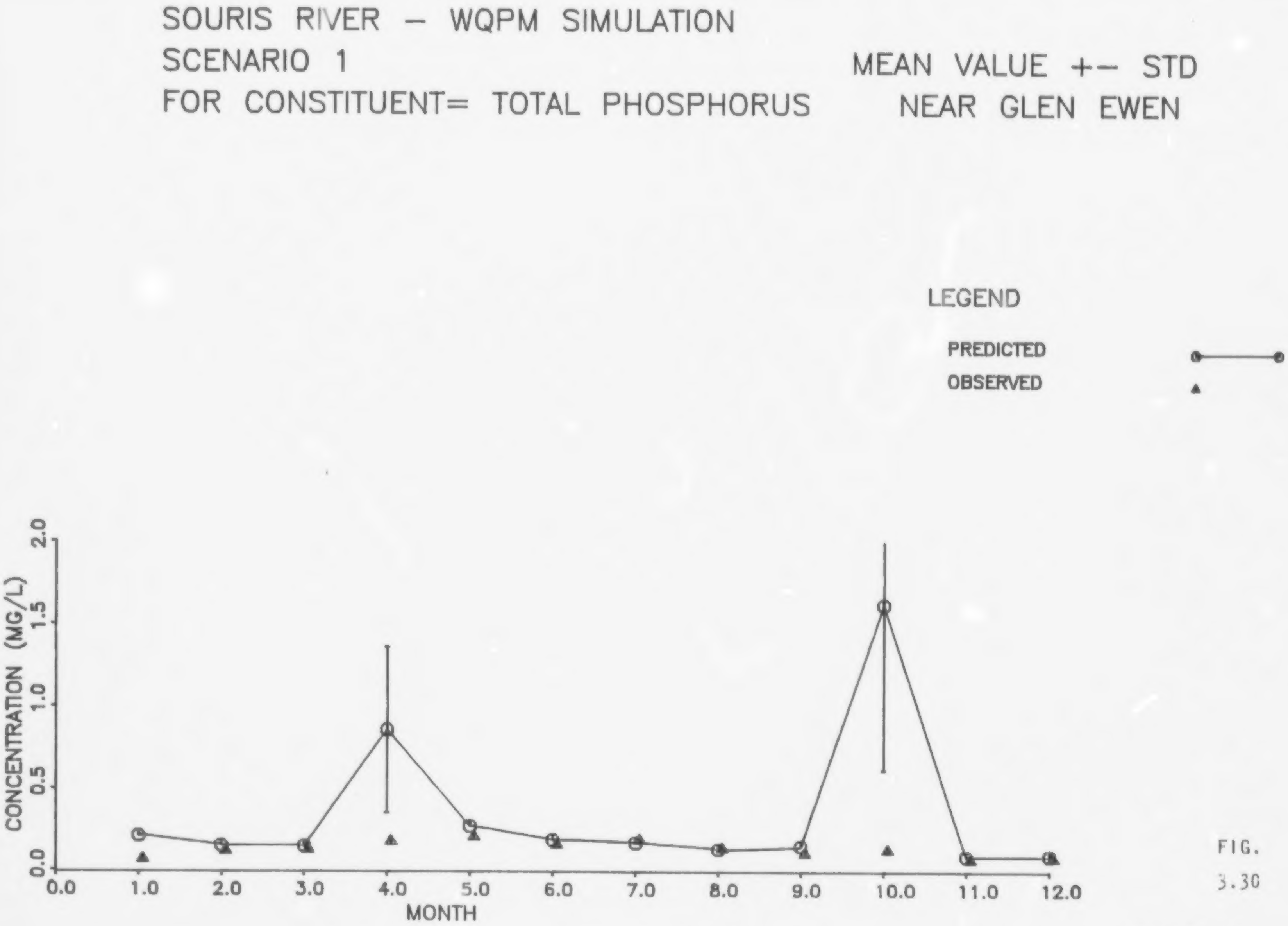

SOURIS RIVER – WQPM SIMULATION
SCENARIO 1
FOR CONSTITUENT= MAGNESIUM
MEAN VALUE +– STD
NEAR GLEN EWEN
LEGEND
PREDICTED
OBSERVED
CONCENTRATION (MG/L)
0.0
25.0
50.0
75.0
100.0
125.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
MONTH
HydroQual Inc.

FIG. 3.29

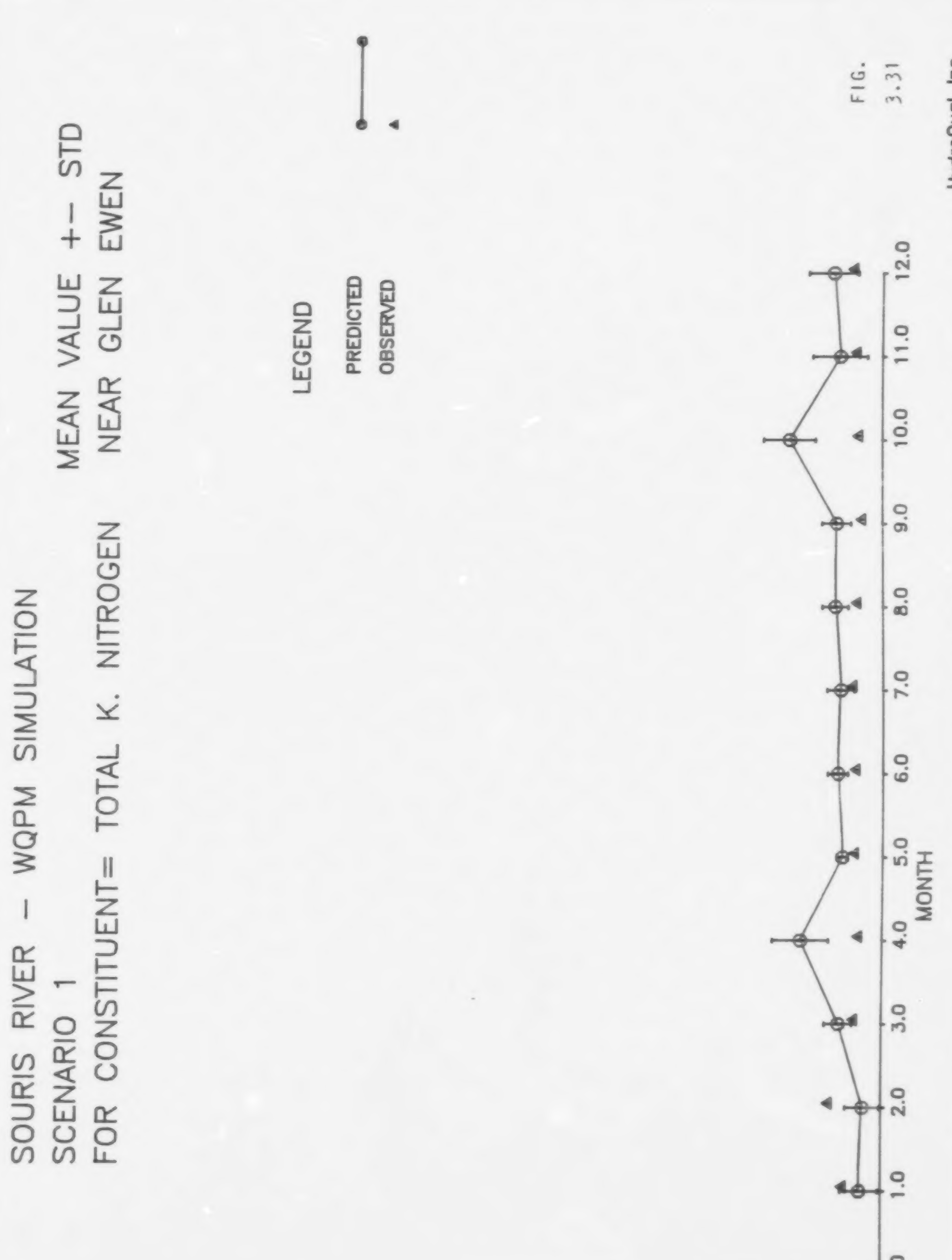


SOURIS RIVER – WQPM SIMULATION
SCENARIO 1
FOR CONSTITUENT= TOTAL PHOSPHORUS

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.30

HydroQual Inc.



SOURIS RIVER – WQPM SIMULATION
SCENARIO 1
FOR CONSTITUENT= TOTAL K. NITROGEN

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.31

HydroQual Inc.

3.3 Simulated Water Quality Conditions - Scenario 2

Scenario 1 assumed that the reservoir would be filled rapidly during a high flow year, i.e. 1955. This rapid fill is followed by a series of low runoff years from 1956 to 1968. High flows were again experienced in 1969. This may be an overly optimistic scenario from a water quality perspective because the reservoirs enter a dry period being full of relatively good quality water.

Scenario 2 assumes that the reservoir does not fill as rapidly, but rather the dam is closed at the start of a sequence of low flow years. This simulation was facilitated by simulating the interval from 1956 to 1974, and ignoring 1955. Reservoir elevations at the start of the simulation were assumed to be 538.7 m for Rafferty and 566.7 m for Alameda. Although the water balance was changed from Scenario 1 due to the altered storage regime, the consumptive demands and operating rules remained the same. All inflow and effluent quality conditions were the same as scenario 1.

Figures 3.19 and 3.20 compare reservoir elevations for Scenarios 1 and 2 over the simulation interval. Rafferty Reservoir remains low for the entire interval from 1956 to 1968, whereas Alameda Reservoir experiences low elevations from 1960 to 1968. After 1968 the between-scenario differences in elevation are reduced.

3.3.1 Reservoir Quality - Scenario 2

Relative to Scenario 1, average reservoir quality is altered substantially for some parameters (Table 3.10). The effect is most pronounced for Rafferty Reservoir, while average conditions in Alameda vary to a lesser degree.

Table 3.10 Comparison of average reservoir concentrations between Scenarios 1 and 2. Units are mg/L except conductivity (usie/cm) and SAR (relative units). Standard deviation indicated in parentheses.

Alameda Reservoir

	Scenario 1	Scenario 2
TP	0.038 (0.024)	0.045 (0.026)
TKN	2.18 (0.27)	2.19 (0.27)
Cond	525 (140)	506 (139)
Ca	40 (7)	40 (7)
Mg	24 (7)	23 (6)
Na	46 (18)	45 (20)
Cl	10 (3)	10 (3)
SAR	1.4 (0.4)	1.4 (0.5)

Rafferty Reservoir

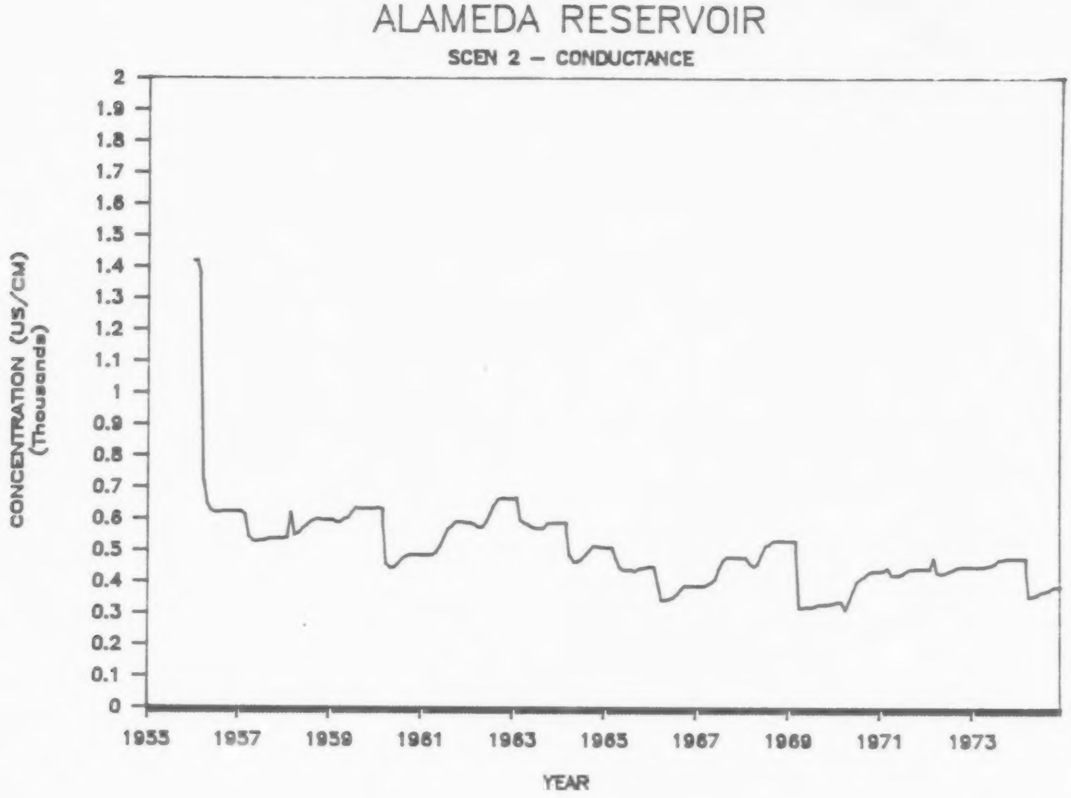
	Scenario 1	Scenario 2
TP	0.049 (0.025)	0.126 (0.073)
TKN	3.00 (0.69)	3.67 (1.97)
Cond	559 (125)	652 (266)
Ca	45 (9)	49 (18)
Mg	24 (5)	24 (11)
Na	47 (14)	63 (2)
Cl	18 (4)	19 (11)
SAR	1.4 (0.3)	1.8 (0.6)

Conductivity levels in Rafferty attain a maximum of 1350 usie/cm in 1968, as compared to 900 usie/cm for Scenario 1 (Figure 3.32). The effect of spill from Boundary in 1965 and 1966 is that conductivity levels dro dramatically because of the reduced Boundary storage capacity. The yearly variability in Rafferty is much more pronounced as compared to Alameda, where salinity levels are relatively stable across the nineteen years.

The pattern for major ions (Figures 3.33 to 3.36) is similar to that of conductivity. Average concentrations in Alameda remain similar to those of Scenario 1, whereas, maximum values for Rafferty Reservoir are substantially higher. Concentrations in Rafferty may have gone higher had the spill from Boundary Reservoir not occurred. The SAR levels in Alameda Reservoir generally remain below 2.0, whereas values in Rafferty Reservoir approach 4.0 in late 1968 (Figure 3.37).

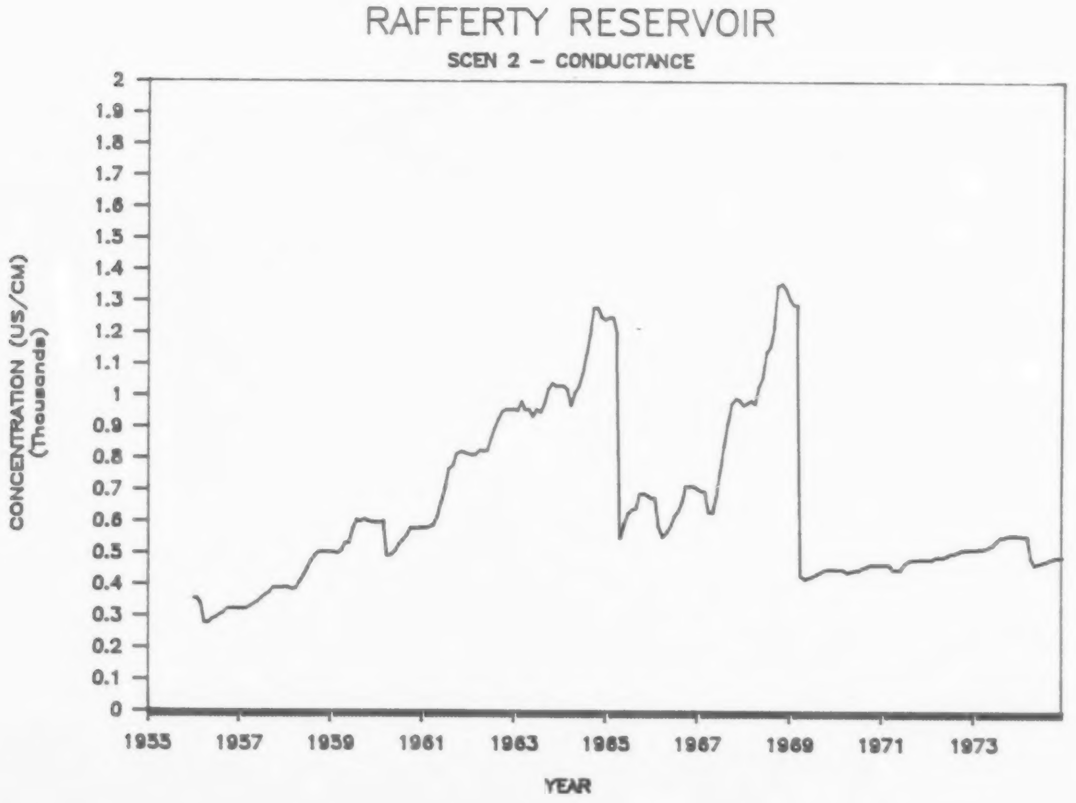
Total phosphorus and total nitrogen conditions in Alameda Reservoir remain largely unchanged relative to Scenario 1 (Figures 3.38, 3.39). On the other hand levels in Rafferty Reservoir are increased substantially, 0.049 to 0.126 mg/l for TP, and 3.00 to 3.67 mg/l for TN. These elevated nutrient levels in Rafferty would translate into a corresponding increase in average and maximum chlorophyll levels (Table 3.11). These conditions would definitely place Rafferty in the hypertrophic range of trophic classification.

At the extremely low reservoir elevations experienced on Rafferty during Scenario 2, winter oxygen would be completely depleted in late February (Table 3.12). Conditions in Alameda Reservoir would remain largely unaltered relative to Scenario 1, i.e. average levels should remain above 5.0 mg/l.



ALAMEDA RESERVOIR

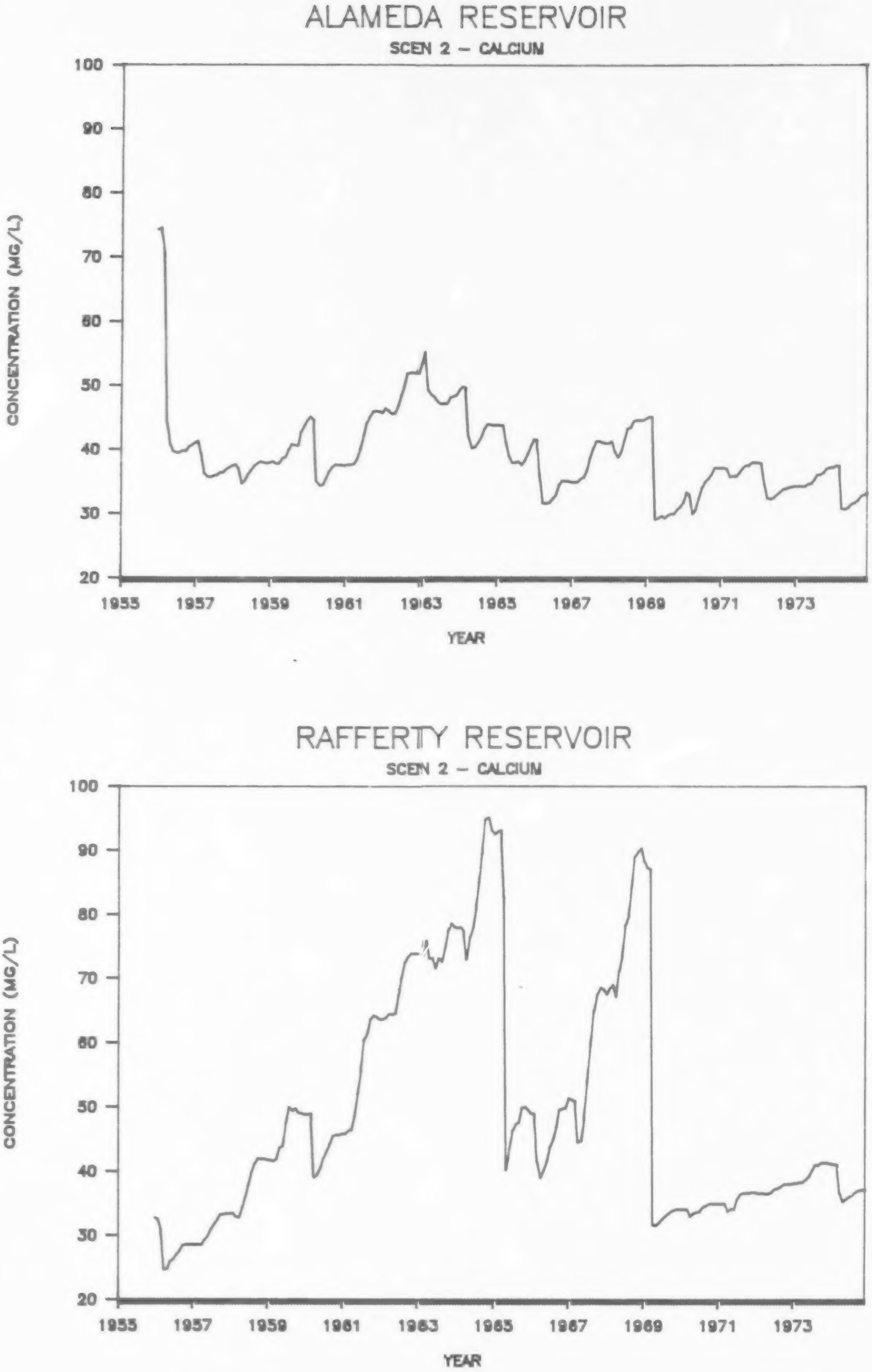
SCEN 2 – CONDUCTANCE



RAFFERTY RESERVOIR

SCEN 2 – CONDUCTANCE

FIG.
3.32



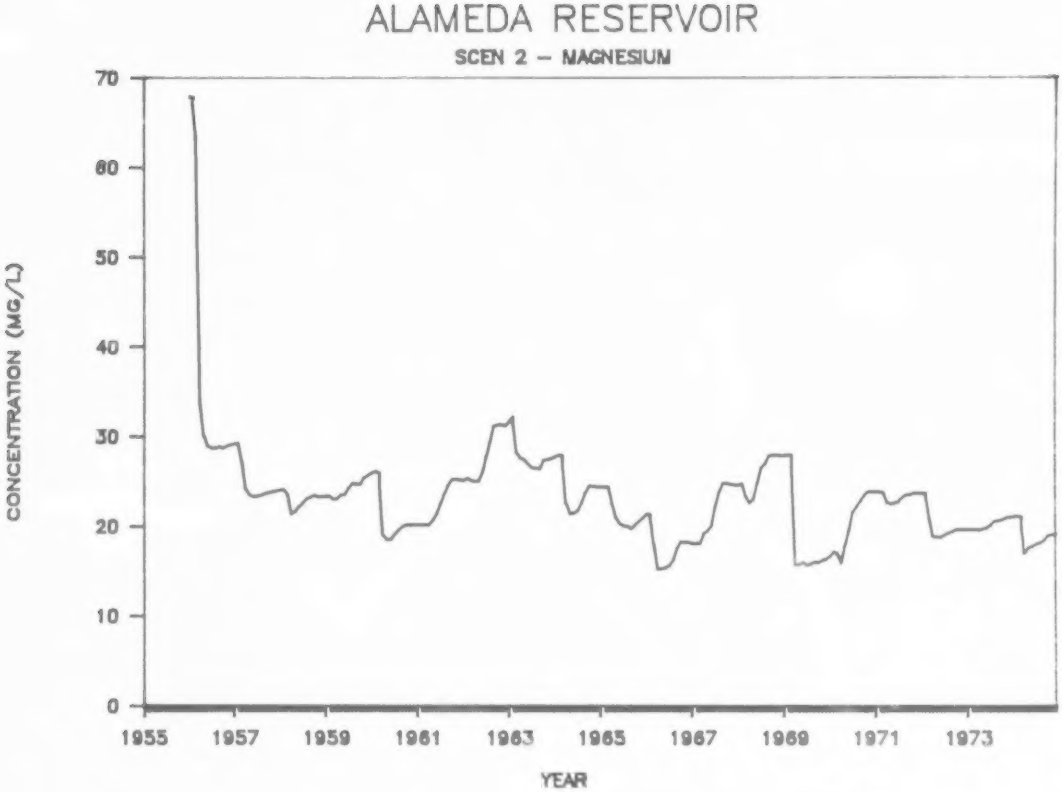
ALAMEDA RESERVOIR

SCEN 2 – CALCIUM

RAFFERTY RESERVOIR

SCEN 2 – CALCIUM

FIG. 3.33


ALAMEDA RESERVOIR
SCEN 2 – MAGNESIUM
CONCENTRATION (MG/L)
70
60
50
40
30
20
10
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

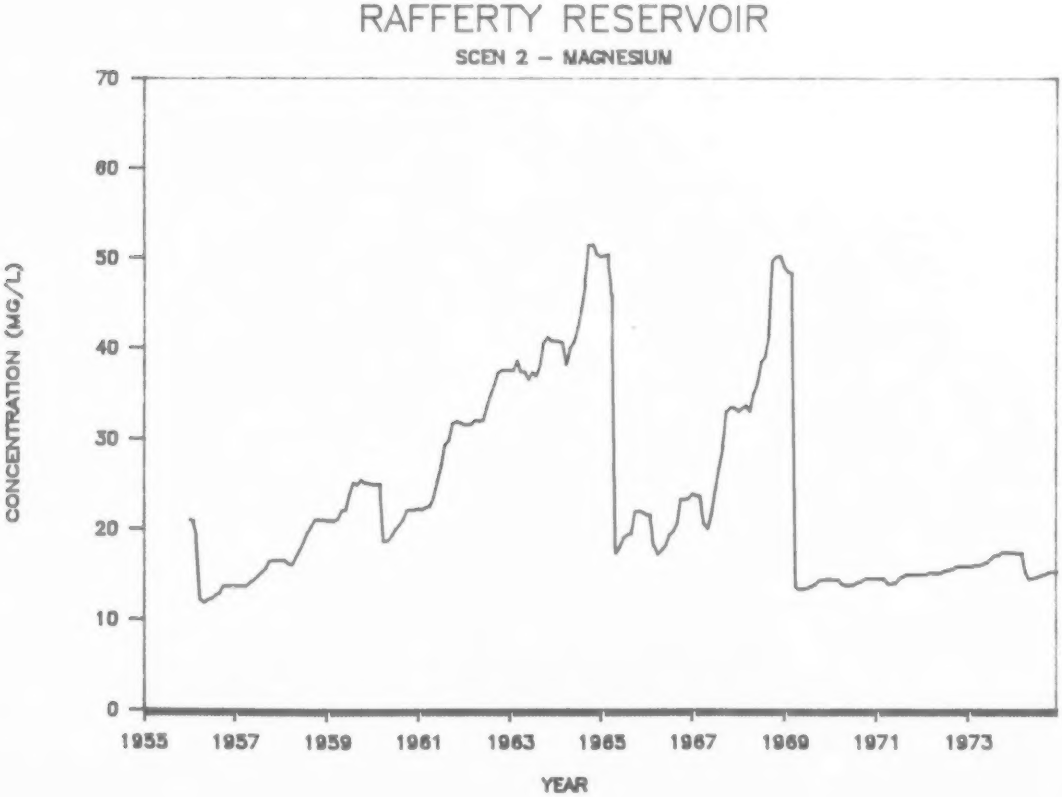
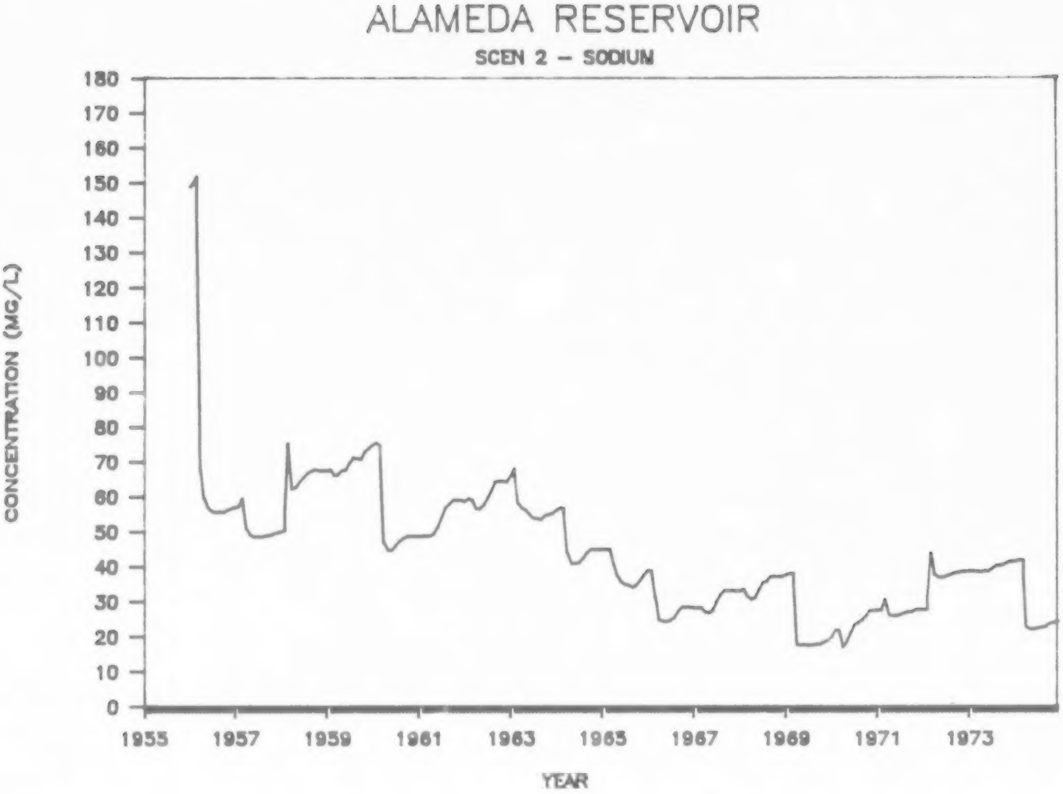

RAFFERTY RESERVOIR
SCEN 2 – MAGNESIUM
CONCENTRATION (MG/L)
70
60
50
40
30
20
10
0
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.34


ALAMEDA RESERVOIR
SCEN 2 – SODIUM
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

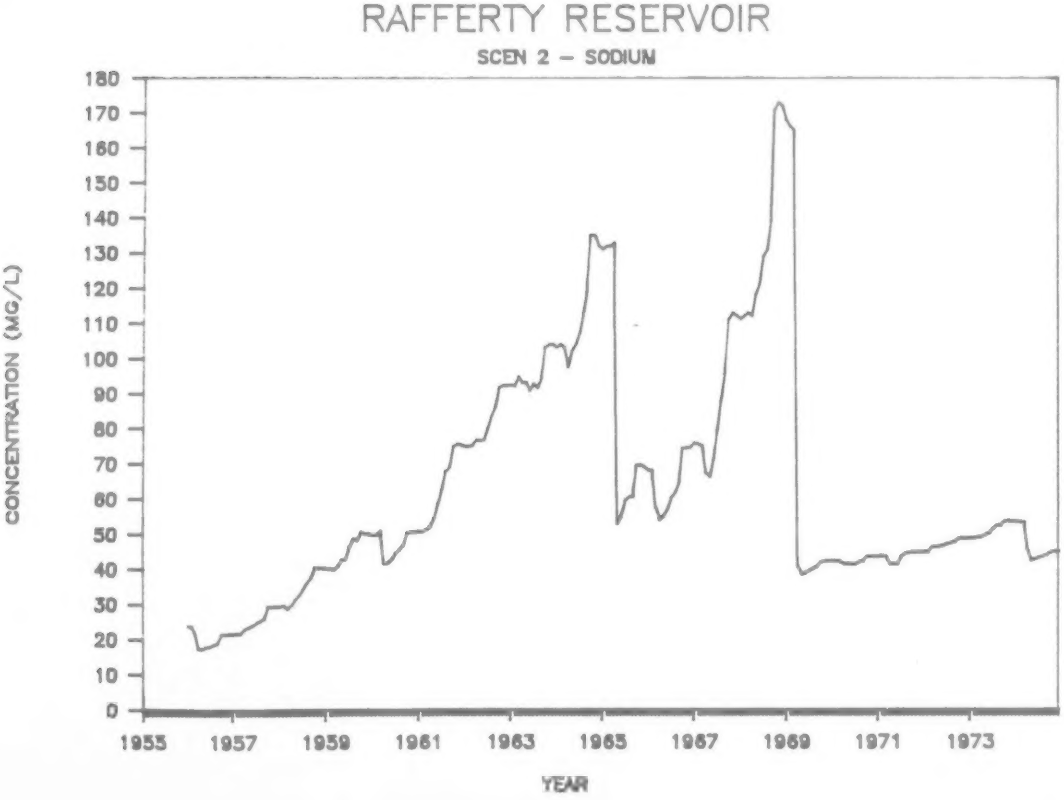
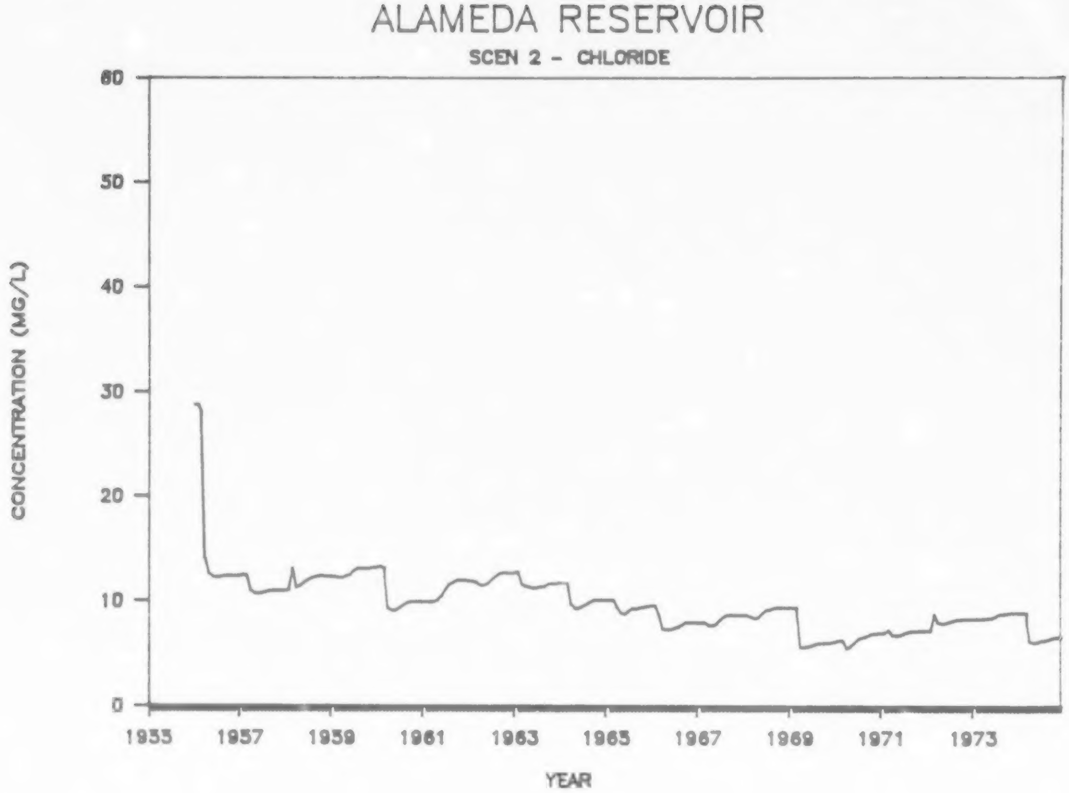

RAFFERTY RESERVOIR
SCEN 2 – SODIUM
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.35


ALAMEDA RESERVOIR
SCEN 2 - CHLORIDE
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

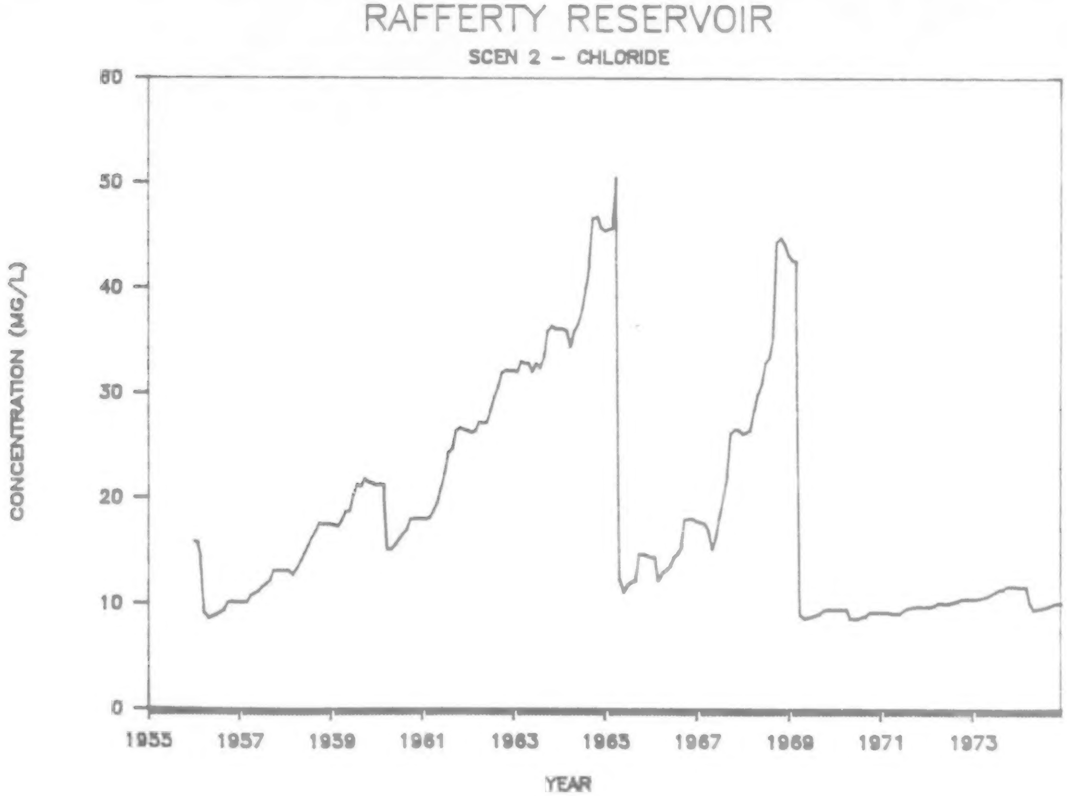

RAFFERTY RESERVOIR
SCEN 2 - CHLORIDE
CONCENTRATION (MG/L)
0
10
20
30
40
50
60
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.36

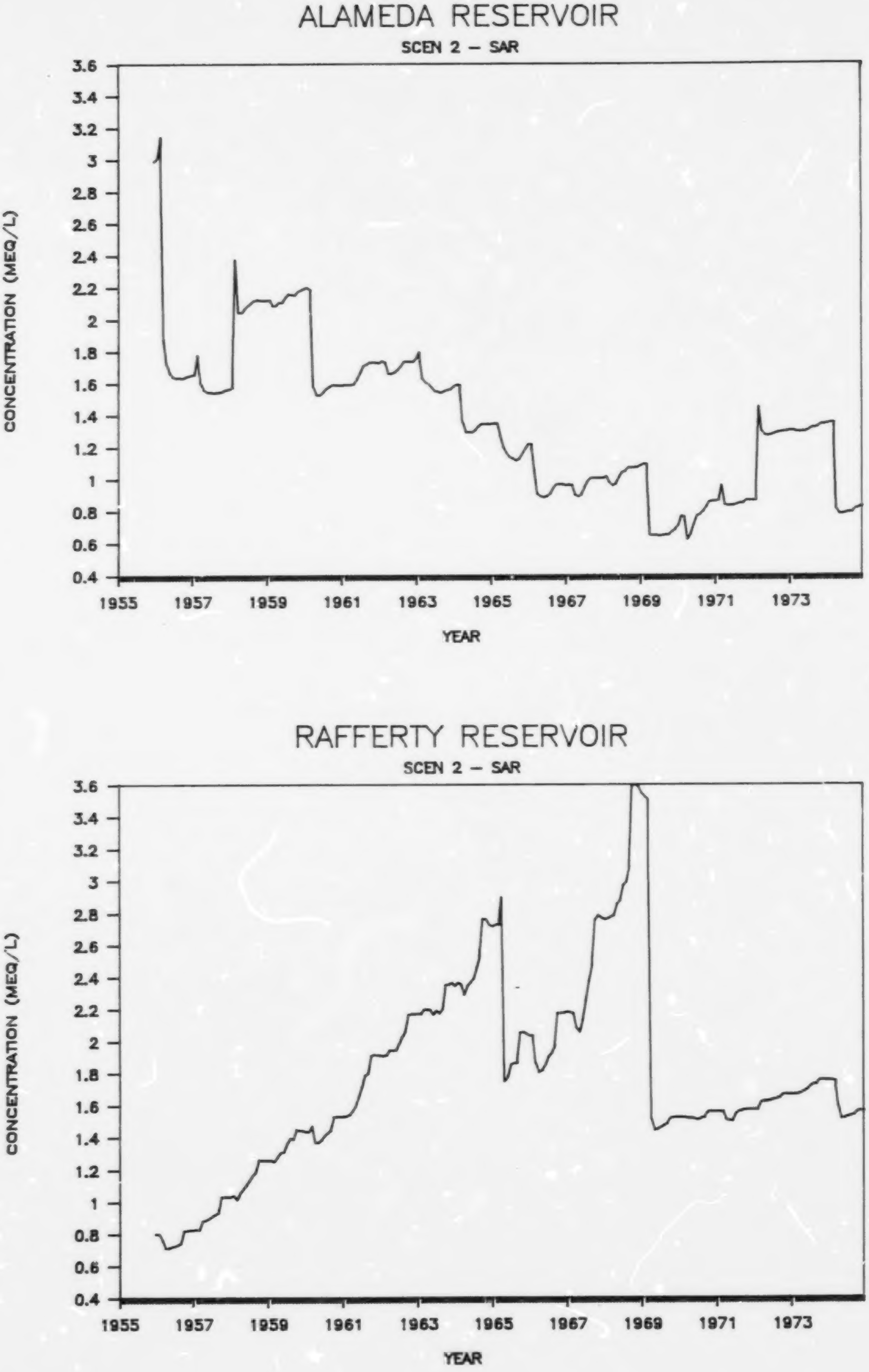
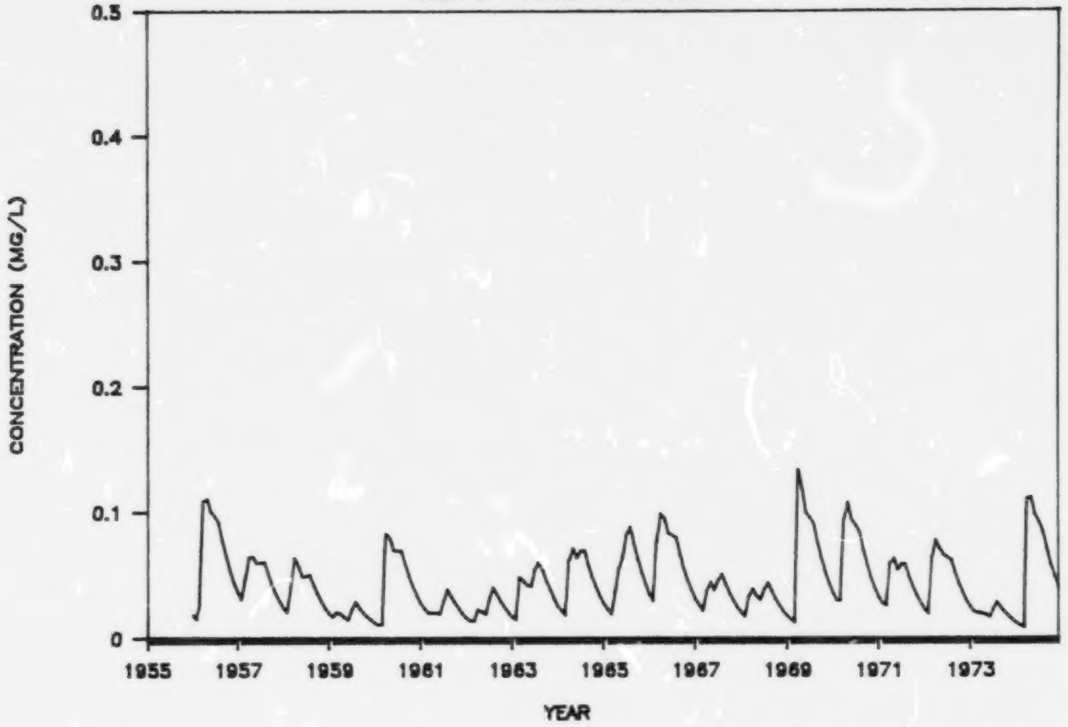

ALAMEDA RESERVOIR
SCEN 2 – SAR
CONCENTRATION (MEQ/L)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR
RAFFERTY RESERVOIR
SCEN 2 – SAR
CONCENTRATION (MEQ/L)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
YEAR

FIG.
3.37

ALAMEDA RESERVOIR

SCEN 2 – TOTAL PHOSPHORUS



RAFFERTY RESERVOIR

SCEN 1 – TOTAL PHOSPHORUS

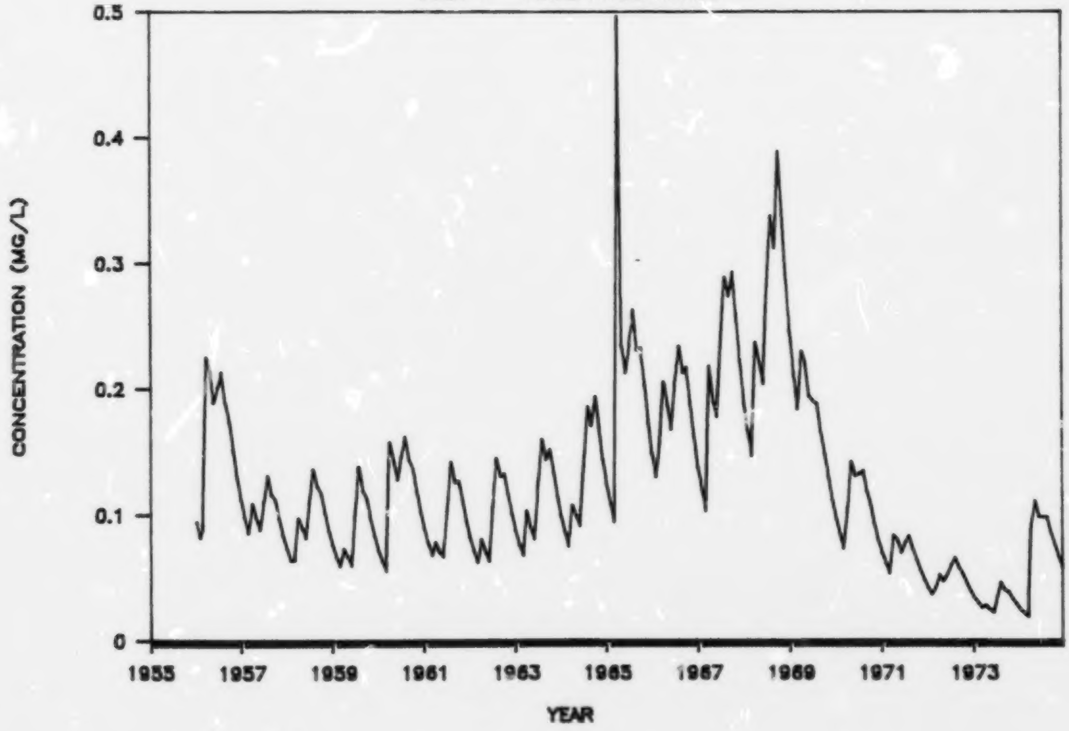
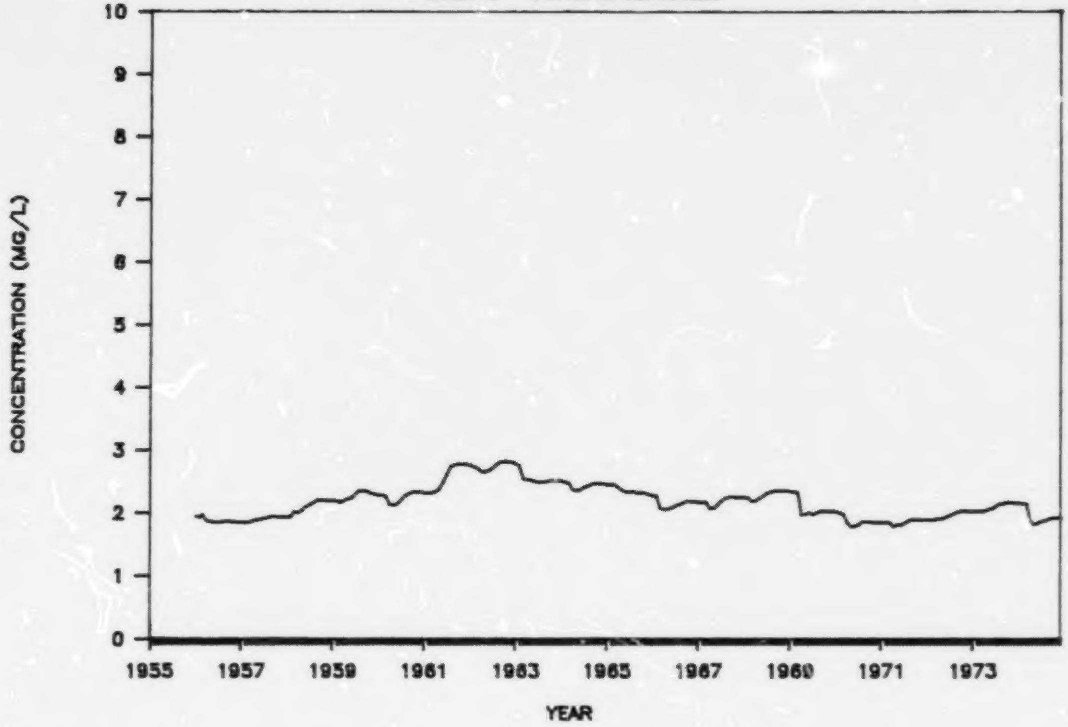


FIG. 3.38

ALAMEDA RESERVOIR



RAFFERTY RESERVOIR

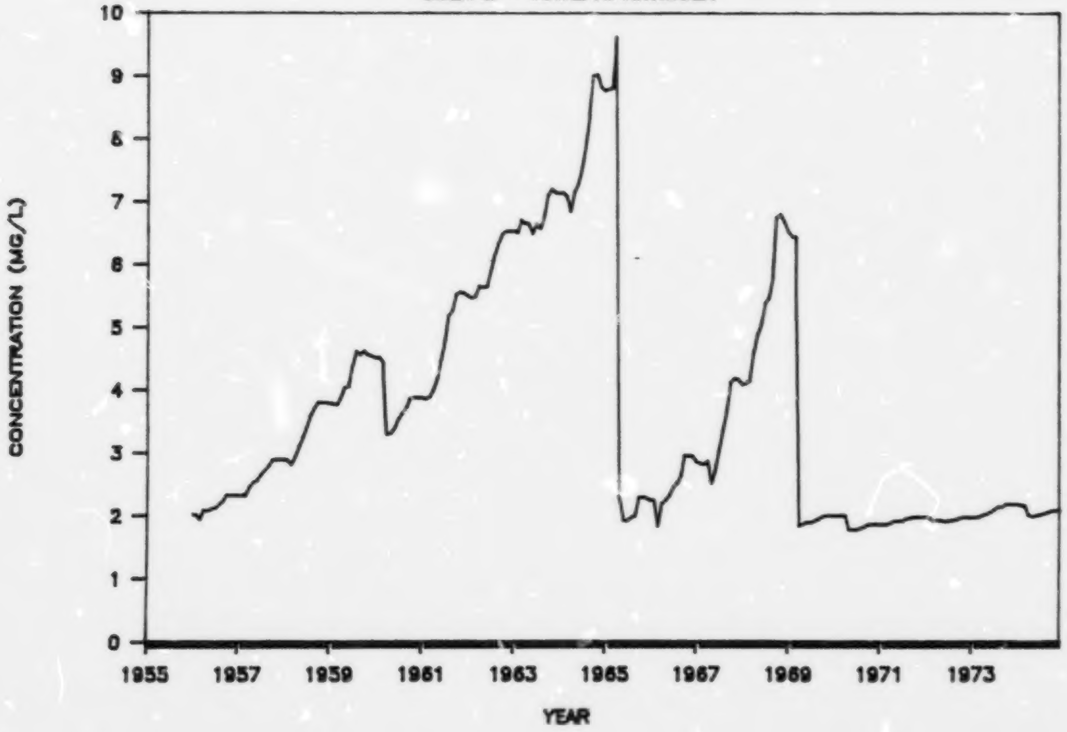


FIG. 3.39

Table 3.11 Comparison between Scenarios 1 and 2 for algal biomass as expressed by chlorophyll$_a$ (mg/m^3).

	Alameda Reservoir	
	Scenario 1	Scenario 2
Average Chlorophyll[1]	14	17
	(10)[2]	(11)[2]
Maximum Chlorophyll	28	33
	Rafferty Reservoir	
	Scenario 1	Scenario 2
Average Chlorophyll[1]	19	56
	(13)[2]	(31)[2]
Maximum Chlorophyll	37	100

---

[1] Prepas and Trew 1983.

[2] Vollenweider and Kerekes, 1981.

Table 3.12 Comparison of winter oxygen predictions at low water level for Scenarios 1 and 2. Based upon depletion rate model of Babin and Prepas (1979).

	Alameda Reservoir	
	Scenario 1	Scenario 2
Mean depth (m)	5.2	5.0
Predicted O_2 depletion rate (g/m² /day)	0.39	0.38
Predicted O_2 (mg/l)		
December 1	13.0	13.0
January 1	10.7	10.6
February 1	8.4	8.3
March 1	6.3	6.2

	Rafferty Reservoir	
	Scenario 1	Scenario 2
Mean depth (m)	4.4	1.0
Predicted O_2 depletion rate (g/m² /day)	0.36	0.24
Predicted O_2 (mg/l)		
December 1	13.0	13.0
January 1	10.5	7.4
February 1	7.9	0.0
March 1	5.6	0.0

3.3.2 Downstream River Conditions

Figures 3.40 to 3.47 present Scenario 2 average water quality conditions at Glen Ewen. Flows are reduced relative to Scenario 1, especially for June. Average water quality conditions in the river remain largely unchanged. There are some increases in winter ion chemistry, and some June values are slightly elevated. This implies that releases from Alameda, and diffuse source inflows, will be major factors regulating water quality in the lower Souris River reaches.

3.4 Other Quality Considerations

3.4.1 Rafferty and Alameda Reservoirs

Since all relevant water quality parameters could not be modelled due to the complexity required or the unavailability of suitable background and calibration data, various parameters or parameter groupings were reviewed on a qualitative basis and are intended to complement the model simulations. These projections or comments of other water quality considerations are based on experience elsewhere, technical judgement, and existing quality data. In some cases emphasis is placed on those parameters related to probable water uses and applicable seasonal considerations.

.1 Physical Characteristics

Turbidity and suspended and settleable materials will be introduced into the reservoirs with the inflowing water, by local runoff, by erosion of banks, and by suspension of bottom sediments due to wind action. Based on upper Souris River data, turbidity loads during the spring period could be substantial. It is expected that

SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= FLOW

MEAN VALUE +– STD
NEAR GLEN EWEN

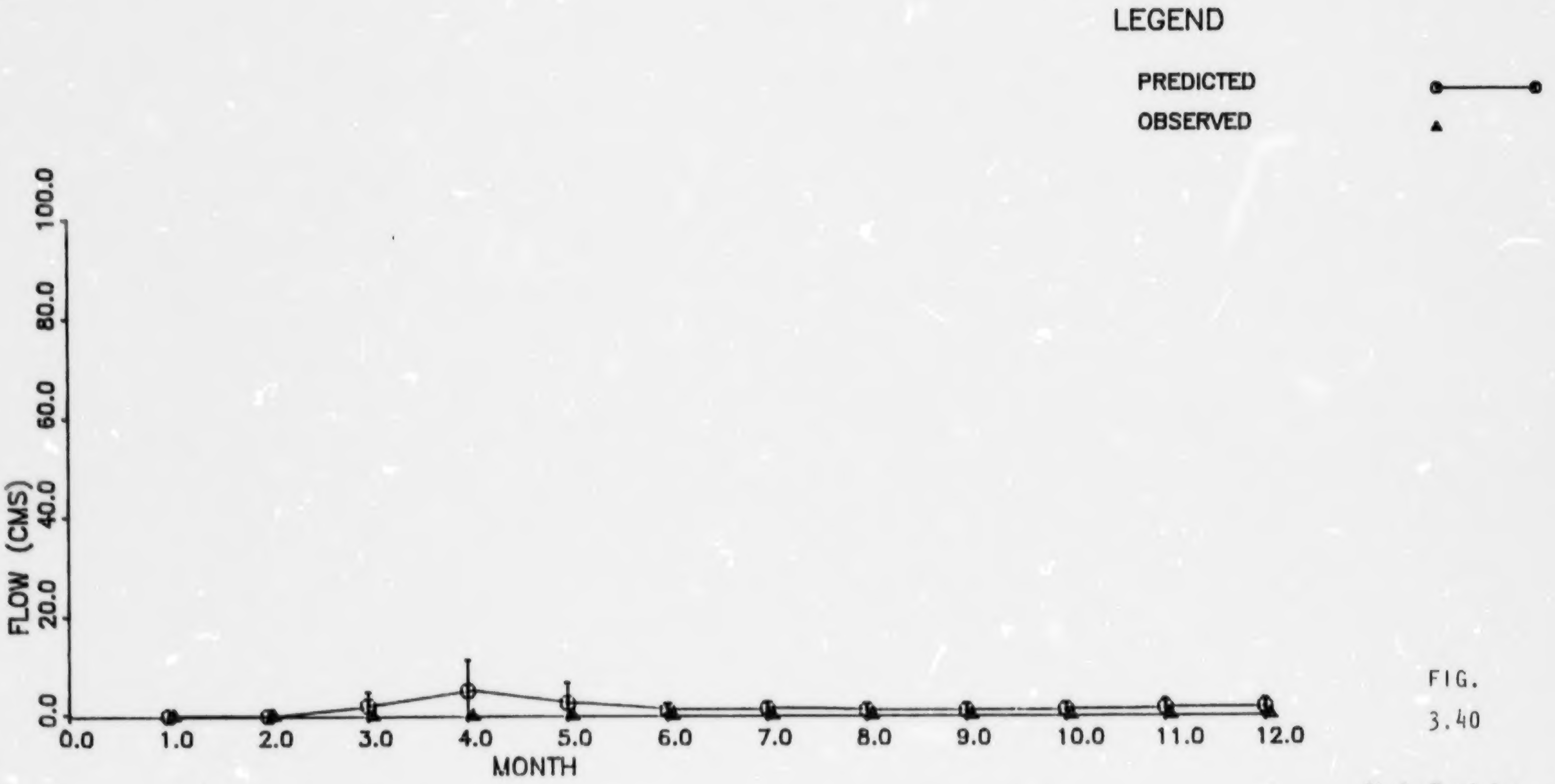


FIG. 3.40

HydroQual Inc.

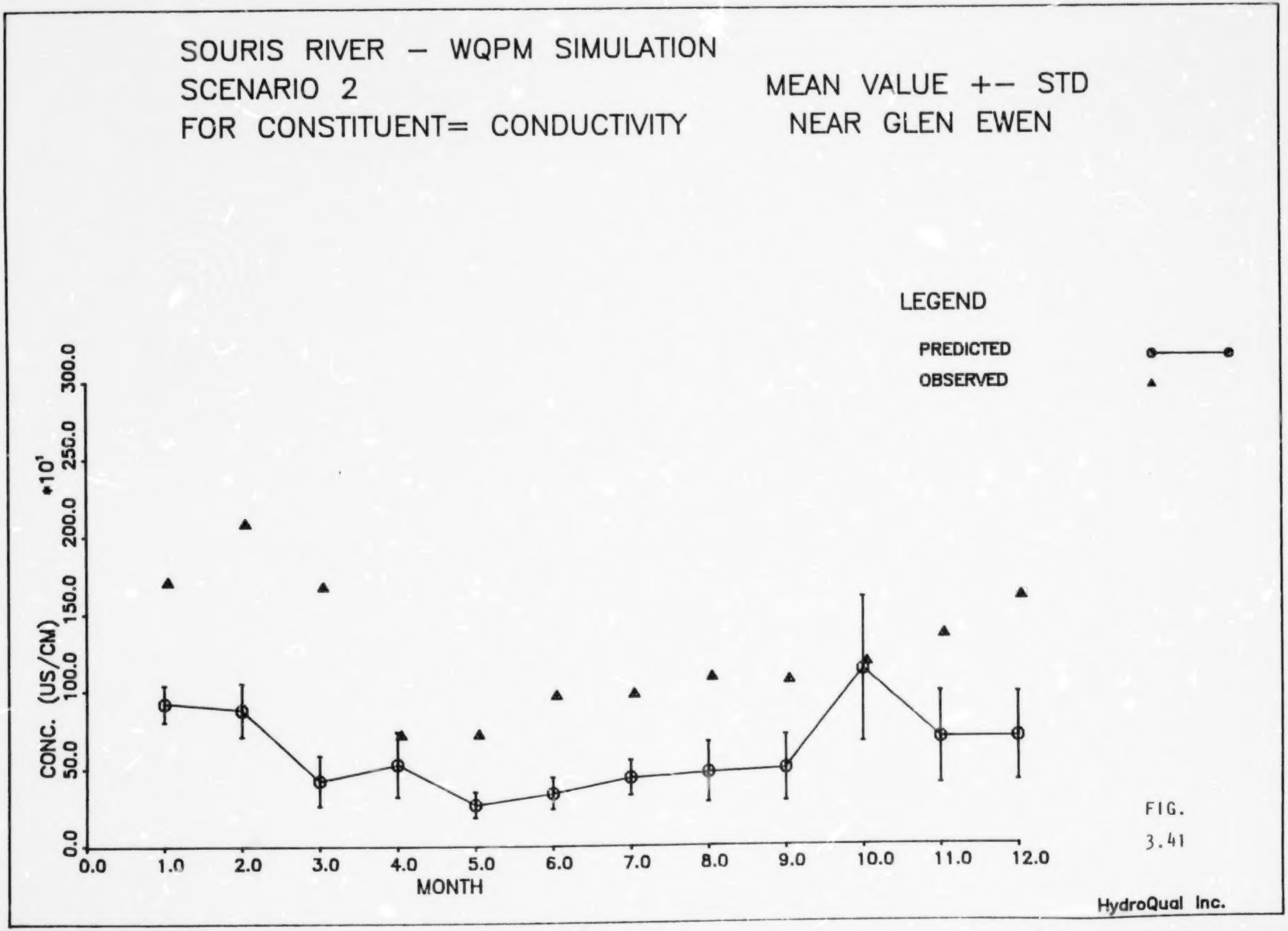


FIG. 3.41

HydroQual Inc.

SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= SODIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

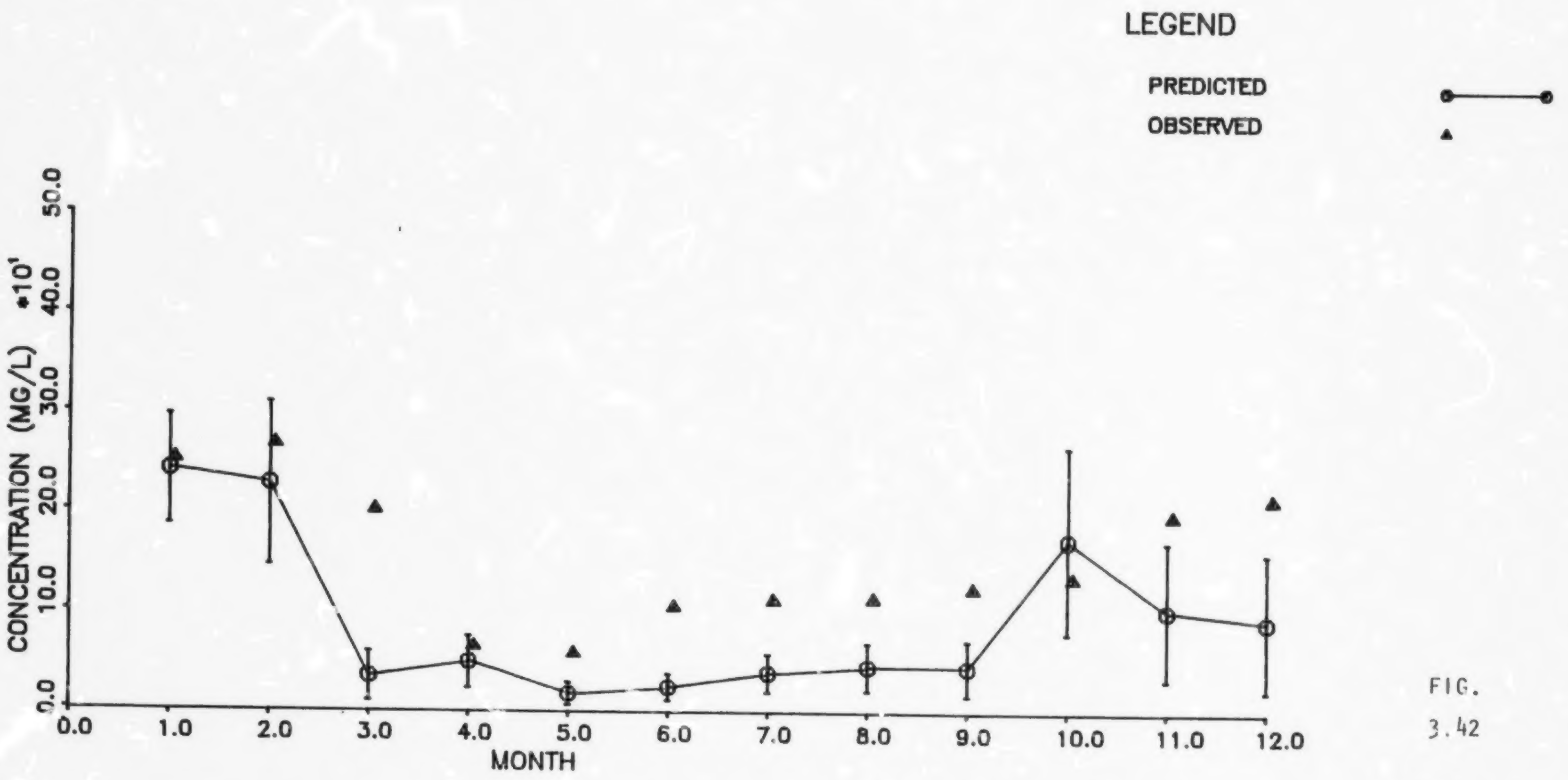
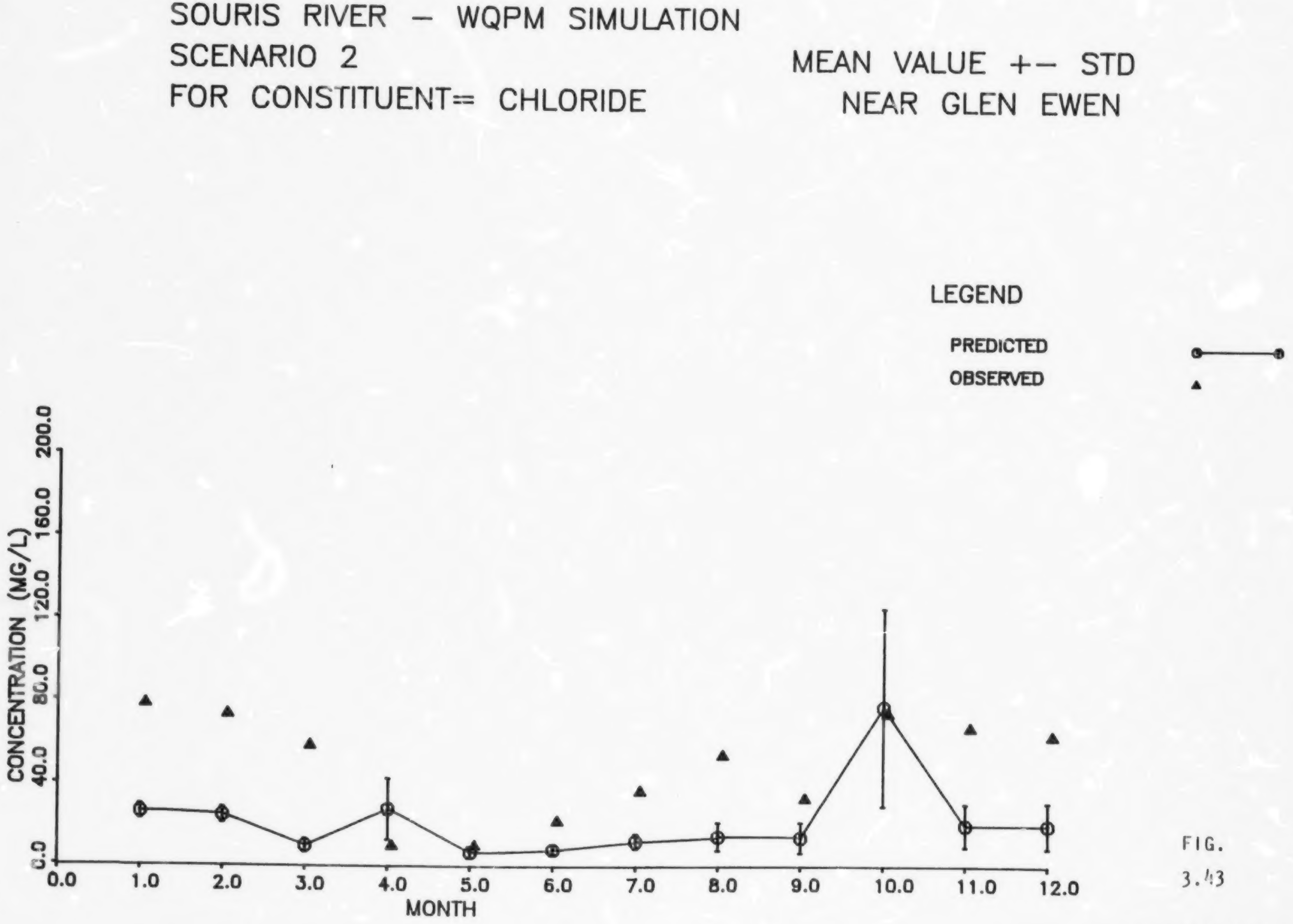


FIG. 3.42

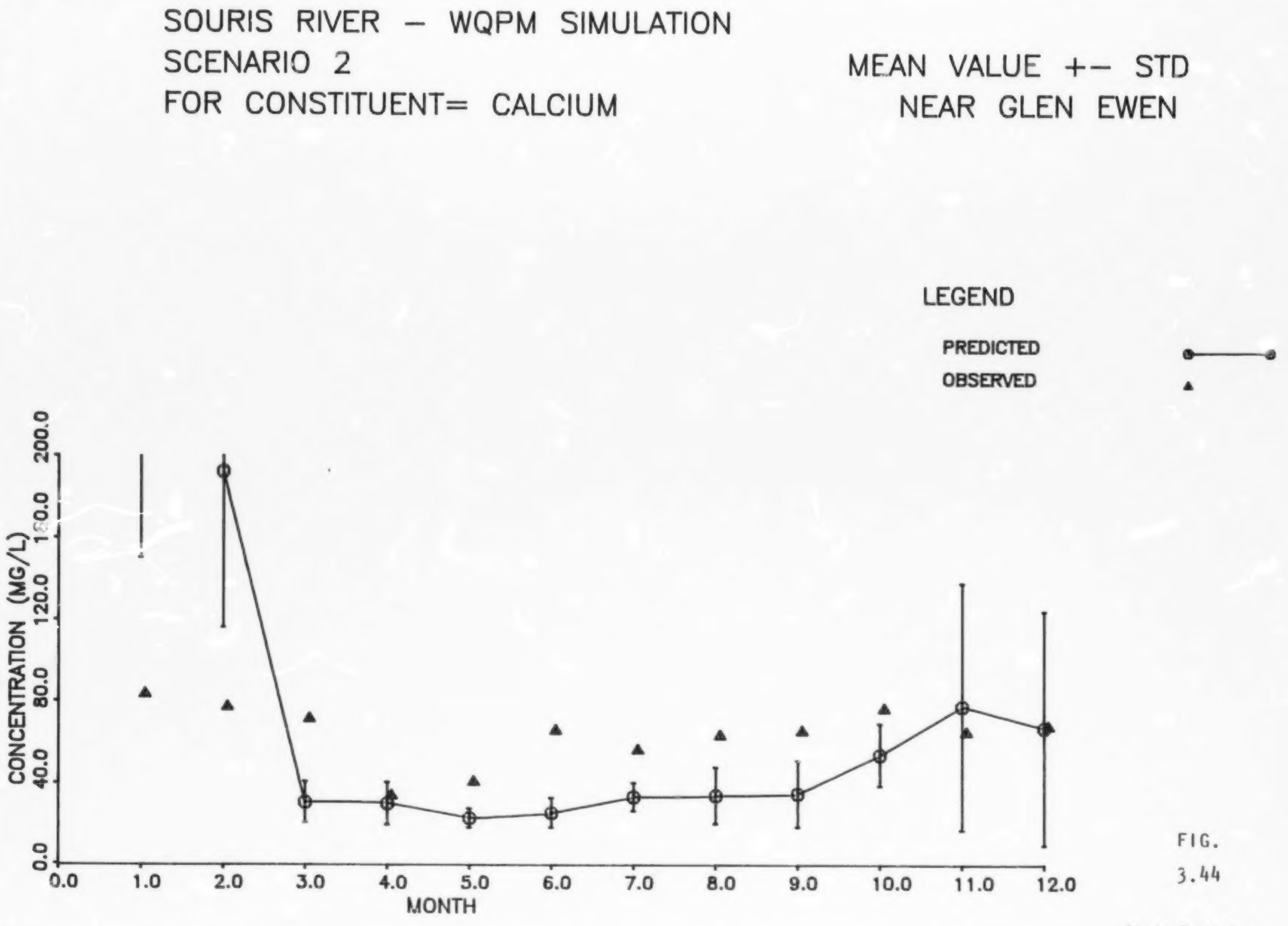
HydroQual Inc.


SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= CHLORIDE

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.43

HydroQual Inc.

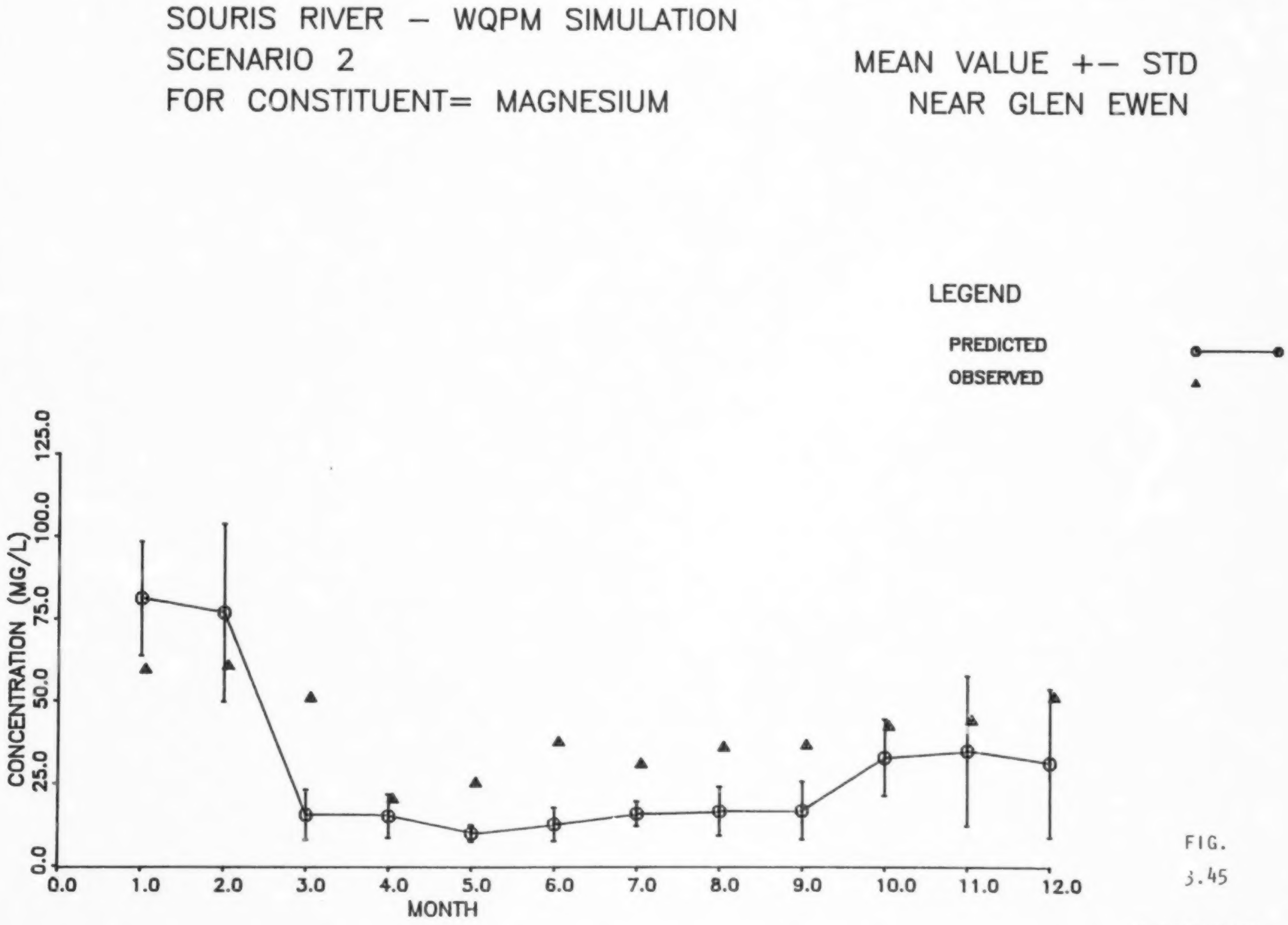


SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= CALCIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.44

HydroQual Inc.



SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= MAGNESIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.45

HydroQual Inc.

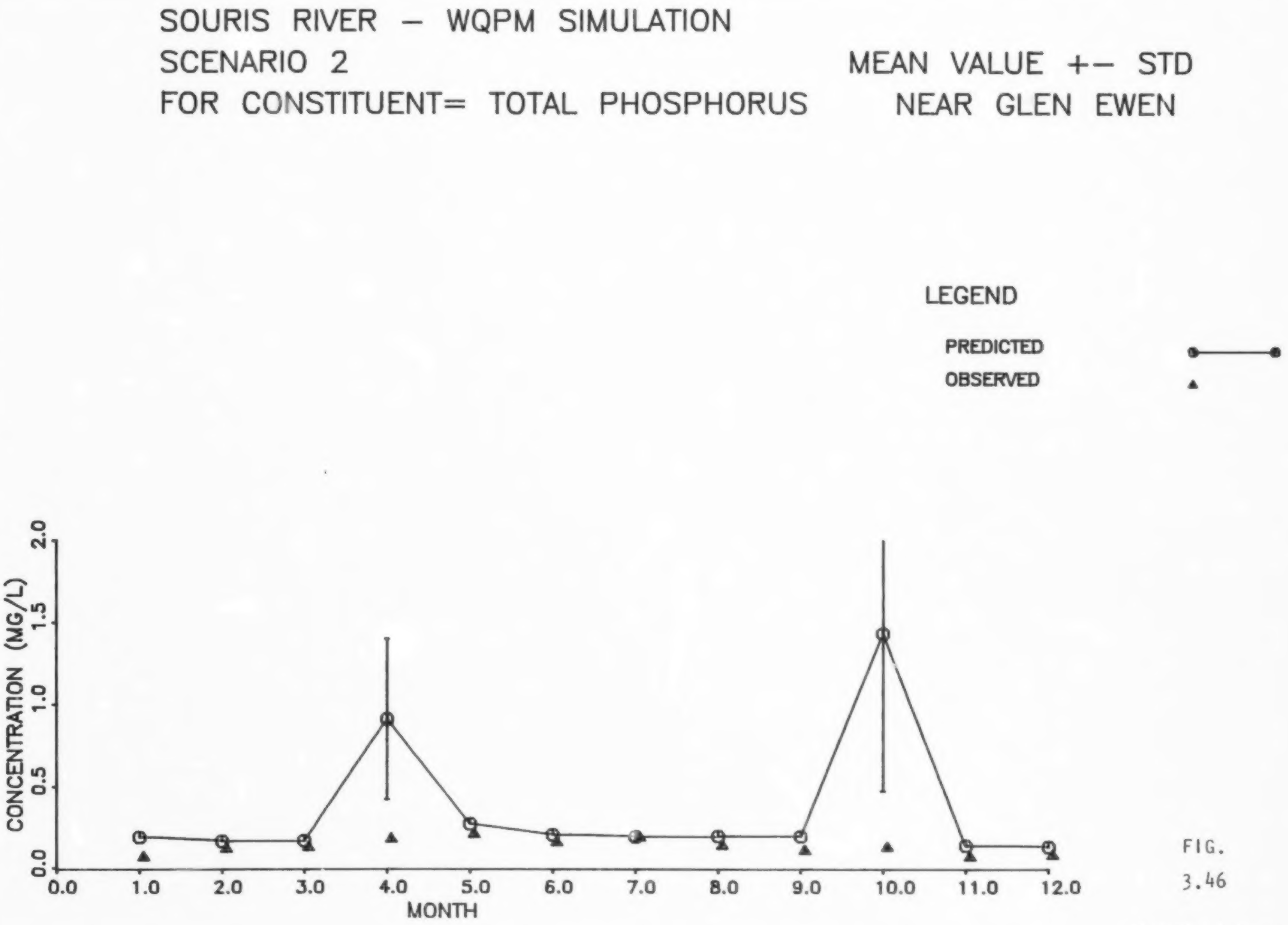
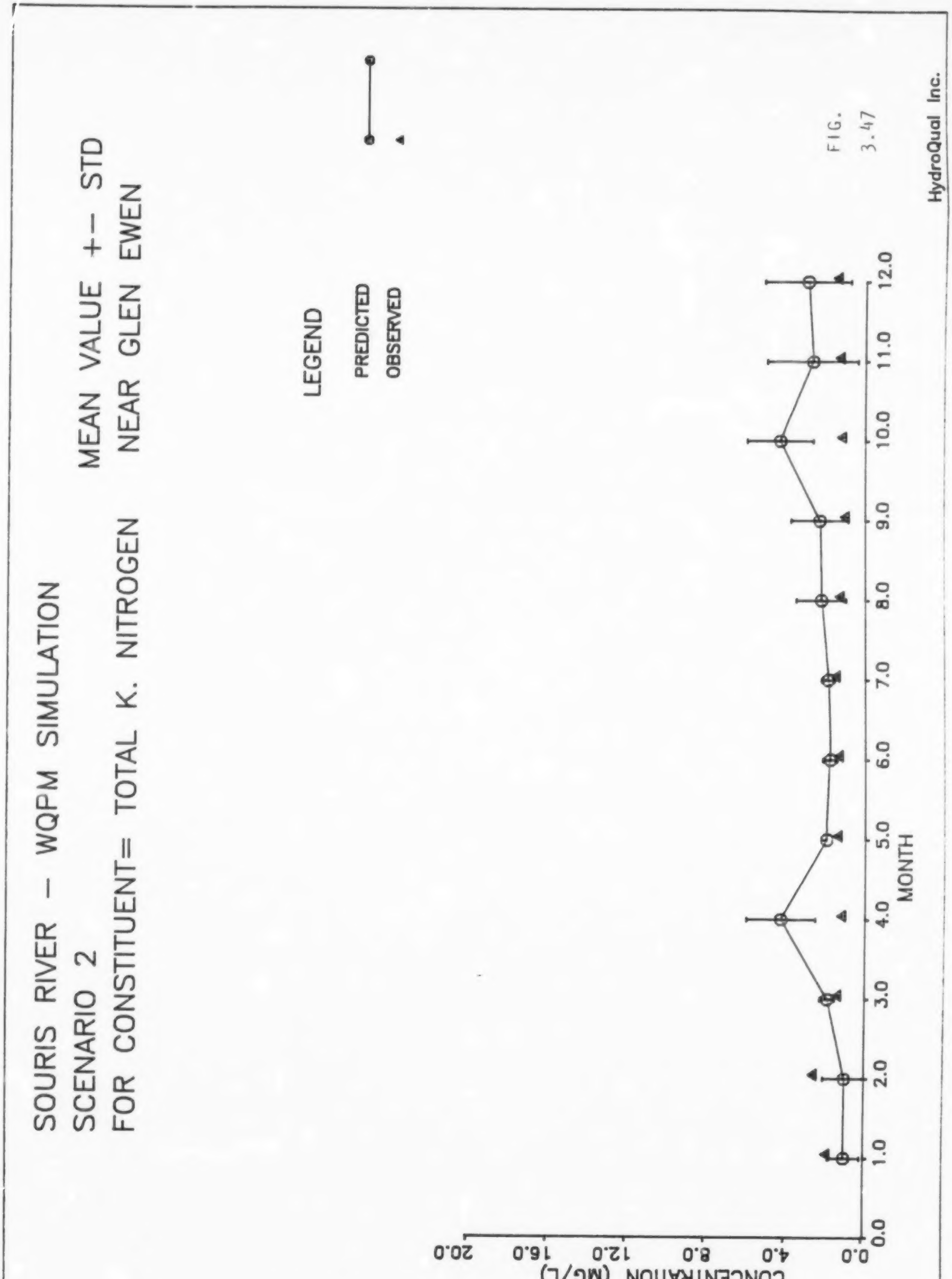


FIG. 3.46

HydroQual Inc.



SOURIS RIVER – WQPM SIMULATION
SCENARIO 2
FOR CONSTITUENT= TOTAL K. NITROGEN

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.47

snowmelt runoff and heavy precipitation events will introduce suspended material and cause localized areas of high turbid waters near the entry points until sedimentation occurs. Available turbidity information for Moose Mountain Creek indicates that Alameda Reservoir may be less susceptible to inflowing turbidity than Rafferty. Induced turbidity arising from the erosion of reservoir banks is difficult to predict as it will depend on water level fluctuations, wind forces, and bank stability such as vegetation growth or the presence of non-erodible, cohesive exposed soils. Rafferty Reservoir, due to greater fluctuating levels, longer fetches for wind action, and the length of shoreline will probably be more prone to this input than Alameda. The re-suspension of sediments will largely be related to the water depth and the action of wind causing stirring or disturbance of the bottom. Due to depth variations, it is expected that Rafferty again can experience more turbidity from this source than Alameda. On balance, Rafferty Reservoir could be more susceptible to higher turbidity than Alameda Reservoir. The amount of turbidity or suspended particulates is expected to vary with the season and the nature of the particular location. Sheltered areas or areas containing significant emergent vegetation, which will act as protective covers, should have fewer occasions of high turbidity. Shallow or exposed areas in the upper portion of the reservoir are likely to experience incidents of high turbidity during high wind conditions, particularly until the reservoir matures.

Colour is normally imported to water through the release of humic and fulvic acids from decaying vegetation or from small oxidized particles of metals, such as iron and manganese. In Southern Saskatchewan, colour production is often related to very low or non-existent dissolved oxygen levels in the water, which tends to promote dissolution of metals from sediments and the production of the vegetation originated colour. For both reservoirs, it is expected that colour development will be rather minimal except in shallow areas subject to substantial organic demands and oxygen depletions under ice cover. The colour values for the upper Souris River have been reported at fairly high levels, particularly during the springtime. It is expected that the presence of colour would be generally localized and would only persist through the late winter months or early stages of spring runoff. Values in Moose Mountain Creek have tended to be lower. It is expected that some of this would be due to shallow wetlands drainage during runoff events. Colour levels in excess of 15 units could be anticipated at various times and locations within both reservoirs.

Under ice cover, temperatures in the reservoirs should vary from approximately 0°C near the surface to perhaps 3°C or 4°C in deep portions. Summer temperatures would depend on climatic conditions and water depths. In the absence of thermal regime modelling, an estimate of potential temperatures can be assessed on the basis of comparative data from lakes in the general geographical area and with somewhat similar morphometry. For this purpose, the best available data from a reservoir not used specifically for cooling purposes are that from Katepwa, Crooked, and Round Lakes. A comparison of the depth features of these Qu'Appelle system lakes with Alameda and Rafferty Reservoirs is summarized in Table 3.13.

Available temperature profile data from Katepwa, Crooked, and Round Lakes over the period 1977 through 1986 for various months and depth increments are presented in Table 3.14. Maximum recorded surface water temperatures have reached 26°C, but normally in the upper 2 m, temperatures ranging from 19°C to 22°C could be expected during the summertime. Generally for the lakes, the upper 10 m has tended to be well mixed with little temperature variation down to that level. Slight declines

TABLE 3.13
WATER DEPTH COMPARISONS

	Depth in Metres			
	Max	Mean	20 Year[1] Mean	20 year[1] Max
Rafferty Reservoir	15.5	8.9	3.7 - 7.8	7.0 - 13.0
Alameda Reservoir	24.0	7.5	5.4 - 6.[illegible]	17.0 - 20.0
Katepwa Lake[2]	23.2	14.3		
Crooked Lake[2]	16.5	7.9		
Round Lake[2]	13.1	7.6		

Notes: [1] - Ranges based on Scenarios 1 & 2.
[2] - Ref. - Qu'Appelle Valley Management Board (1977).

approaching 2°C to 3°C have occurred in the next 6 m increment. In deeper areas such as may be obtained at Alameda Reservoir, bottom water temperatures in the order of 10°C to 12°C may be typical. The temperatures within the main body of the reservoir will be largely dependent on ambient temperatures, mixing, and the depth. In shallow protected areas, temperatures will relate substantially with the atmospheric temperatures and warm waters could be obtained.

.2 Heavy Metals and Trace Substances

Souris River waters have generally exhibited very low levels of heavy metals. This has similarly occurred in Moose Mountain Creek. Often many of the metals are associated with turbidity and particulates and as such would be amenable to sedimentation and loss through this mechanism. Some releases of heavy metals

TABLE 3.14

OPEN WATER TEMPERATURE PROFILES KATEPWA, CROOKED, AND ROUND LAKES

Month	Year	Lake[1]	Temperature Ranges (°C) at Water Depths (m)					
			0 - 2	3 - 4	5 - 6	7 - 10	11 - 16	17 - 22
May	1977	K	11.5	11.5	11.5	11.5 - 10.0	10.5 - 7.0	7.0 - 6.5
	1980	K	10.5 - 10	10	9.5	9.0 - 8.0	6 - 4	4 - 4
		C	13 - 11	11 - 15.5	11.5 - 10	11 - 6	6 - 3.5	--
		R	14 - 12	12 - 11	11.0	11 - 6	6.0	--
June	1977	K	19 - 16	16.5 - 16	16 - 15.5	15.5 - 14.5	15.5 - 14.5	15 - 14.5
		C	18.5 - 16	18.5 - 16	18.5 - 16	18.5 - 15	15	--
		R	18.5 - 18	18.5 - 18	18.5 - 17.5	18.5 - 17.5	17.5	--
	1979	K	14.5 - 10	10 - 9.5	10 - 9.5	9.5 - 9	9 - 8	8.5 - 7.5
		C	16.5 - 13.5	15.5 - 12	14.5 - 12	12.5 - 10.5	11 - 10	--
		R	17 - 14.5	15.5 - 14	13.5 - 12.5	13 - 12	12	--
	1981	K	15 - 14.5	15 - 14	15 - 14	15 - 14	15 - 11.5	13.5 - 11
		C	16 - 15	16 - 15	15	15	15	--
July	1977	K	20 - 18.5	19 - 18	18	18 - 16.5	16 - 10.5	11.5 - 9
	1983	C	25 - 21.5	23 - 21.5	23 - 21.5	22 - 20.5	20.5 - 19	--
		R	26 - 22.5	23.5 - 22	23 - 22	22 - 21.5	21.5	--
Aug	1977	K	17 - 16	16.5 - 16	16.5 - 16	16.5 - 15.5	16.5 - 15.5	15.5 - 12
		C	18.5 - 16.5	17 - 16.5	17 - 16.5	17 - 16.5	16.5	--
		R	18 - 17.5	17 - 16.5	17 - 16.5	17 - 16.5	16.5	--
	1980	K	19 - 18.5	19 - 18	19 - 18	19 - 17.5	17.10	10 - 8
		C	19.5 - 19	19.5 - 19	19.5 - 18.5	19 - 18	18.5 - 17	--
		R	20 - 19	20 - 19	20 - 19	20 - 19	--	--
	1981	K	24 - 22	22 - 21.5	22 - 21	21.5 - 20	20 - 15	16 - 13
		C	22.5 - 21.5	22 - 21	22 - 20.9	22 - 19.5	21 - 18	--
		R	23 - 22	22 - 21.5	22 - 21.5	21.5 - 21	--	--
	1983	K	21 - 20.5	21 - 20	20.5 - 21	20.5	20 - 12	12.5 - 11
	1985	K	21 - 20.1	20.6 - 20	20.5 - 19.8	20.3 - 18.5	20.1 - 15.2	15.7 - 14
		C	18	18	18	18	18	--
		R	18	18	18	18	18	--
	1986	K	20.8 - 19.2	19.5 - 19	19.5 - 18.9	19 - 17.7	17.8 - 9.3	12.8 - 11.2
		C	21 - 19.5	19.5 - 19.4	19.5 - 18.7	19.3 - 19.3	18.3 - 17.3	--
		R	21.4 - 19.7	19.6 - 19.5	19.5 - 19.1	19.1 - 18.8	18.8 - 18.7	--
Sept	1977	K	13.5	13.5	13.5	13.5	13.5	13.5
	1979	K	15	15	15	15	15 - 14.5	15 - 13
		C	15	15	15	15 - 14.5	15 - 14	--
		R	15	15	15	15	15	--

Note: Raw data from Water Quality Branch, Saskatchewan Environment and Public Safety.

[1] Lakes: K - Katepwa
C - Crooked
R - Round

from sediments or inundated soils could occur under anaerobic or anoxic conditions at the bottom of the reservoir, which may be experienced particularly under ice cover. However, the amount or significance of this source is unknown. No characterization of future inundated soils was available for comparative purposes. Based on information from Nickle Reservoir, problems associated with heavy metals have not been reported. It is anticipated that concentrations of heavy metals will not, on average, exceed current surface water quality objectives or guidelines, although localized exceptions both vertically and at various sites within the reservoirs may occur. It is unclear whether the Alameda or Rafferty would become more affected, although the greater depth and lesser flooded area of Alameda may make it less susceptible from heavy metal pickup from inundated areas.

Of the trace substances, boron may be the most significant. Based on available data, boron in excess of 0.5 mg/L has been observed a number of times. Although boron may precipitate and settle out as a borate under special water column characteristics, it is expected boron could also tend to increase through concentration in similar manner to total dissolved salts and the major ions. Boron concentrations in the soils to be covered are unknown, but it is expected that soils will yield some boron through a leaching process.

.3 Mercury in Fish Tissue Concerns

Since the early 1970s discovery of elevated mercury levels in fish tissue from the South Saskatchewan River, there has been ongoing concerns and surveys respecting fish tissue mercury content concentrations in Saskatchewan waters and their acceptability for human consumption. While mercury use has largely been curtailed, previous uses and natural mercury concentrations in the soils may provide sufficient sources to promote a problem. Biologically methylated mercury from inundated sediments or the water column is assimilated by various aquatic organisms, which in turn tend to magnify concentrations up to the ultimate end of the aquatic food chain, the fish. Thus fish can accumulate considerable mercury concentrations through the biomagnification process even though ambient source levels appear to be low.

Water column mercury levels in the Souris River basin waters have tended to be low, although incidence of positive detections in the ng/L range have been observed. Mercury levels in soils to be flooded by Rafferty Reservoir for 8 sites were reported in the Soils report to the overall EIS as ranging from 0.11 to 0.27 kg/ha (furrow slice) with a mean of 0.16 kg/ha. Assuming a 15 cm depth and potential dry weight soil densities, the resultant conversion yields mean concentrations in the order of 53 to 66 ug/kg (ppb). Alameda project soil data are not available. Boundary Reservoir sediment collected during 1983 from the lower portion of the lake had mean dry weight ranges of 66 to 77 ppb. These values tend to be similar to that found in Qu'Appelle Fishing Lakes and somewhat higher than observed in Cookson Reservoir on the Poplar River system.(Saskatchewan Environment 1983, Waite et al. 1980) Even though Cookson Reservoir had low sediment mercury values and low mercury concentrations in contributing waters, mercury in fish was detected at relatively high levels shortly after flooding.(Waite, et al. 1980)

Unfortunately, no fish tissue mercury data are available for Nickle Lake.(Pers. Comm., Saskatchewan Environment 1987) Table 3.15 illustrates some fish tissue mercury concentrations in Cookson Reservoir, Boundary Reservoir, and Crooked and Round Lakes in the Qu'Appelle system at various periods. It is noted that the original high levels encountered at Cookson Reservoir were reduced in a short time for the game fish to below unrestricted levels for human consumption. Based on the Cookson Reservoir

TABLE 3.15
MERCURY IN FISH
SELECTED SASKATCHEWAN DATA

Waterbody	Fish	Year	n	Average Hg in Fish Tissue(ppm)
Cookson Reservoir	*Stizostedion vitreum* (walleye)	1979[1]	14	1.04
		1983[2]	27	0.23
		1984	15	0.25
	Moxostoma macrolepidotum (red horse sucker)	1979[1]	10	0.22
	Catostomus commersoni (common sucker)	1979[1]	15	0.28
Crooked Lake	*Stizostedion vitreum* (walleye)	1979	25	0.30
		1981	35	0.36
		1982	16	0.49
		1984	25	0.27
	Esox lucius (northern pike)	1979	14	0.33
		1981	2	0.26
		1982	1	0.18
		1984	8	0.12
	Perca flavescens (yellow perch)	1979	22	0.27
Round Lake	*Stizostedion vitreum* (walleye)	1981	36	0.45
		1982	8	0.59
		1983	24	0.50
		1984	23	0.40
	Esox lucius (northern pike)	1981	5	0.21
		1983	8	0.33
		1984	9	0.36
	Perca flavescens (yellow perch)	1983	5	0.18
	Lota lota (burbot)	1981	2	0.08
	Stizostedion vitreum (walleye)	1983	27	0.23
Boundary Reservoir	*Stizostedion vitreum* (walleye)	1974[3]	11	0.31
		1982[3]	10	0.43

1. Waite, Dunn & Stedwill (1980)
2. 1983 Annual Report - Poplar River Bilateral Monitoring Committee, March 1984.
3. Sask Environment (1983)

experience and other literature references, there is potential for newly inundated reservoirs to provide a source of mercury for accumulation.

Based on the potential for mercury in the inundated sediments to become available through the food chain, it is possible that fish within the reservoirs will accumulate mercury in tissue. It is uncertain whether these levels will reach 0.5 ug/g, the current maximum level for unrestricted consumption. It is expected that the availability of mercury will diminish as the reservoirs age and sediments become more stable. Based on the Cookson Reservoir performance, any high concentrations in game fish could similarly decrease with time.

.4 Biocides and Organochlorine Compounds

Based on existing water quality data, inflowing or contributing waters generally contain biocide and organochlorine compound levels below detection limits. Exceptions include the herbicides 2,4-D and the pesticides lindane and its isomer alpha-BHC. These three constituents could well be at detectable levels at various times within the reservoir. The presence of chlorinated organic biocides in soils to be inundated in both reservoirs is unknown, but based on the present land use, no substantive concentrations from agricultural activities would be anticipated. Typically reservoirs and lakes receiving agricultural runoff in this province have had low but measurable concentrations of the three aforementioned constituents. However, problems are not projected.

.5 Bacteriology

Bacteriological organisms of public health and water quality significance would largely be introduced into Rafferty Reservoir through wastewater discharges from Weyburn and from land runoff particularly associated with extensive wildlife or livestock activity and to Alameda Reservoir from the latter source. Weyburn effluent, with the extended storage capability of their treatment facility, will probably cause a lesser problem than previously monitored on the Souris River. With the controlled discharge arrangement in April and October, it is expected that elevated coliform bacteria levels could be encountered in Rafferty Reservoir in the upstream reaches during discharges. However, through natural die off and dilution, the effect of this source would be relatively minor. Other contributions are not defined, but it is expected that no abnormal levels to impair expected uses would occur. This would also apply to Alameda Reservoir. Localized incidents could arise, but this will depend on experience with uses and monitoring would be required to identify any site-specific problems.

.6 Aquatic Biology

As noted in Sections 3.3 and 3.2, nutrient levels (nitrogen and phosphorus) are expected to place Rafferty and Alameda Reservoirs in a eutrophic or fertile classification. Both reservoirs should be favourable for the production of considerable phytoplankton populations and typical diatom, green and blue-green algae species cycling would be expected. Rafferty Reservoir and Alameda Reservoir both may initially experience high atypical phytoplankton populations due to early nutrient release from freshly inundated sediments. After a period of time, this situation should stabilize. However, particularly for Rafferty Reservoir, fluctuations in water levels due to the vagaries of runoff will potentially create shallow warm areas. In the late summer and in sheltered areas, bloom forming blue-green species could develop. The persistence and nuisance causing characteristics of these growths will largely depend on climatic conditions including sunlight, wind, and temperature.

It is expected that a normal typical benthic population will form in the permanently inundated areas of both reservoirs. Pollution tolerant organisms may predominate in shallow areas where severe oxygen depletions may occur.

Emergent and submergent vegetation will largely depend on the substrate available and water level fluctuations. Emergent vegetation such as cattails, bulrush, etc., would be anticipated in the upper reaches of Rafferty Reservoir and in shallow bays. With fluctuating water levels, it is possible that this growth will migrate in accordance with changes in habitat. The presence of rather steep shorelines coupled with varying water levels may inhibit the growth of submergent vegetation in littoral zones of the reservoir. The presence of rooted macrophytes in the bottom, middle, and deep portions of the reservoirs will depend on light penetration and favourable soils. It is expected that aquatic vegetation typical of south Saskatchewan lakes would be viable in both reservoirs.

3.4.2 Souris River Below Rafferty Reservoir

Water quality in the downstream river reaches below the proposed reservoirs will largely be dictated by the water quality in the reservoirs during the period of releases. For the river from Rafferty Reservoir to Moose Mountain Creek, the quality will reflect Rafferty Reservoir quality at the point of release and may be impacted by urban activities including any periodic sewage effluent discharges and stormwater drainage from the city of Estevan, any water uses and return waters from the Estevan generating station, any inputs from the Shand generating station site, and land use activities within the reach. Except for extreme runoff events, Long Creek and releases from Boundary Reservoir will not have a major impact as diversion waters from Boundary Reservoir will be assimilated into Rafferty Reservoir. Downstream of Moose Mountain Creek to the International Border, the water quality will largely be related to the quality of both Alameda and Rafferty Reservoirs, together with local land use activities.

Operation of the reservoirs will markedly change the downstream flow regime during the open water seasons. Spring runoff flows will be drastically reduced for the entire reach to the border. Under full irrigation, summer flows will be increased substantially over that presently experienced. This will be reflected downstream according to irrigation uses but will manifest some increased flows even at the international border. Coupled with the decreased flow regime will be inherent decreases in velocities, especially during the normal spring runoff situations. In addition to the flow regime changes, it is understood that up to 12 low level weirs may be placed in the river channel to facilitate irrigation uses and withdrawals. Following are subjective comments on water quality considerations not included in the simulation process, which are based on projected reservoir quality, proposed flow regimes, and other potential impacts to the river reach.

.1 Physical Characteristics

Due to the sedimentation features within the reservoirs, turbidity levels of the releases are expected to be low unless the discharges coincide with high turbidity conditions within the reservoir. However, at the deep withdrawal points, these incidences would be expected to be few. Since flow rates within the channel will be modified, thus probably inducing less erosion, instream generation of turbidity and suspended particulate matter should also be reduced. The presence of weirs would provide additional settling capability within the reach. While turbidity inputs from surface irrigation waters return and local runoff or discharges would occur, it is anticipated that these would be more than offset by the reductions caused by the other operating and hydraulic features.

Water colour, which naturally reaches high levels due to upstream inflows, potential groundwater discharges, and other characteristics of the river, may be modified due to the entrapment of the spring runoff water in the major reservoirs and increased summer flows resulting from irrigation demands. During the winter period, colour would not be substantially altered over that presently experienced.

Temperature values in the downstream reach have reflected ambient climatic conditions, particularly during the low flow periods of summer and fall. While withdrawal waters from the reservoirs may be cool, it is expected that this water would rapidly warm within short distances downstream. The provision of weir impoundments will permit further warming of the water. Therefore although additional flows will minimize present instream ponding and stagnation, and increase velocities during the summer time, it is anticipated that lower reach temperatures in excess of 20°C would be obtained during the hot summer months.

.2 Heavy Metals/Trace Substances

Due to a potential reduction through sedimentation of heavy metals attached to particulate substances in the reservoirs, heavy metal concentrations are expected to be low in the downstream reach. Trace substances such as boron will largely reflect the quality of the reservoir water. Based on estimates from within the reservoirs, boron will be expected to be higher in the reach to Moose Mountain Creek and reduced in the subsequent reach due to the low values expected in Alameda Reservoir. Values in the 0.5 - 1.0 mg/L range would be anticipated from time to time.

.3 Biocides

Biocide concentrations in the downstream reach are expected to be low unless land use practices and return flows provide a significant input for these chemicals. The potential practices for the use of agricultural chemicals associated with increased irrigation activity is unknown.

.4 Bacteriology

Bacteriological quality of reservoir water is expected to be satisfactory. Major inputs would relate to any discharges from the Estevan sewage treatment facility and to livestock or wildlife activities within the reach. The Estevan lagoon operating regime which provides for twice annual discharges (April and October) would generally preclude any significant incidence of impaired bacteriological quality in the lower reach during critical use periods. However, in the spring the available dilution will be considerably reduced and localized high populations could be experienced during this period. Input of other bacteriological organisms of interest into the system from other land use activities is difficult to predict at this time.

.5 Aquatic Biology

With the low level releases from the reservoirs, the populations of phytoplankton reduced during releases will be minimized. The waters in the lower reach will be sufficiently fertile to support phytoplankton and epilithic growths during the open water period. The anticipated increased flows during the summertime to meet irrigation demands will avoid small pooling although the imposition of weirs for irrigation withdrawals will provide larger reservoirs. Coupled with the projected warm temperatures, it is expected that phytoplankton populations could flourish but possibly not any more severe than presently experienced.

The reduction in spring flows and the attendant loss of scouring capability except for extreme runoff events may provide a more suitable and stable habitat for emergent vegetation. Similarly the loss of scour may permit more sedimentation within the reach and provide substrates for rooted aquatic vegetation. Therefore it is possible that increased growth of submergent and emergent macrophytes could occur in the lower reach.

Since zooplankton populations tend to be influenced by numerous other factors besides phytoplankton abundance, it is difficult to predict any changes which may occur in present populations downstream of the proposed Rafferty and Alameda Reservoirs. Should growths of aquatic vegetation become more common along the Souris River, this may provide additional suitable and protected habitats for zooplankton. However, exactly what changes in terms of numbers and variety of organisms which may result cannot as yet be determined.

Because of their largely sedentary characteristics, benthic invertebrate populations will probably reflect downstream changes due to the Rafferty and Alameda reservoirs to a large extent. With the previously suggested increases in sedimentation caused by the two dams and the proposed weirs, the bottom substrate may be altered significantly and may result in colonization by organisms more suited to the new environment. Again, predictions are difficult because the potential changes in numbers and variety of organisms are influenced by numerous other factors besides type of substrate.

3.5 Summary Projections and Comments

Based on the foregoing review, the potential water quality effects from the construction and operation of Rafferty and Alameda Reservoirs and the attendant uses are summarized in the following Tables 3.16 and 3.17 for the reservoirs and for the downstream river reaches.

TABLE 3.16
RAFFERTY AND ALAMEDA RESERVOIRS
SUMMARY WATER QUALITY COMMENTS

Parameter/ Characteristic	Scenario 1	Scenario 2	Comments
Dissolved Salts			
. Conductance,uS/cm			. Higher values tend to occur in winter seasons.
Rafferty - range	350 - 900	300 - 1350	. Modifies present high winter levels found in Souris River and Moose Mountain Creek.
- average	560	650	
Alameda - range	300 - 750	300 - 700	. Averages lower than present summer and fall median values.
- average	525	510	
. TDS, mg/L(calculated)			
Rafferty - range	270 - 730	225 - 1100	. Within current Sask Municipal Drinking Water Objective.
Alameda - range	210 - 630	210 - 590	
. Total Hardness, mg/L, as $CaCO_3$			
Rafferty - average	215	225	. Calculated from Ca, Mg projections. . Suitable for municipal/ domestic supply.
Alameda - average	200	200	
. Sodium Adsorption Ratio			
Rafferty - range	0.9 - 2	0.8 - 3.6	. Some improvements over present variations.
- average	1.4	1.8	
Alameda - range	0.7 - 2	0.6 - 2.2	. Values generally acceptable for non-restricted irrigation.
	1.4	1.4	

TABLE 3.16 (Cont'd)

Parameter/ Characteristic	Scenario 1	Scenario 2	Comments
Nutrients			
. Total Kjeldahl Nitrogen,mg/L			. Exceeds present median spring-fall values in Souris R. and Moose Mountain Cr. . Exceeds Sask. N objective. . Could yield periodic undesired un-ionized ammonia levels--particularly for Rafferty, Scenario 2. . Will provide nutrients for irrigation water but may stimulate aquatic plant growth.
Rafferty - range	2 - 4.8	1.5 - 9.5	
- average	3.0	3.6	
Alameda - range	1.8 - 2.8	1.8 - 2.8	
- average	2.2	2.2	
. Total Phosphorus, mg/L			
Rafferty - range	0.02 - 0.13	0.02 - 0.5	. Values below present open water median levels. . Sask objective will be periodically exceeded - particularly for Rafferty Scenario 2. . P loading on Rafferty will yield mesotrophic to hypertrophic conditions and on Alameda mesotrophic to eutrophic status. . Sufficient to promote and sustain aquatic vegetation growths.
- average	0.05	0.13	
Alameda - range	0.01 - 0.12	0.01 - 0.12	
- average	0.04	0.05	
Dissolved Oxygen			
Rafferty	May get conditions less than 5 mg/L under ice cover in shallow areas and in lower depths of deep areas summer and winter. More extensive winter depletions - to anoxic conditions could occur under Scenario 2.		. Could adversely affect fish life in localized areas. . Oxygen levels should be generally adequate except during long-term shallow depth conditions, which depend on hydrological sequences.
Alameda	Generally should maintain concentrations in excess of 5 mg/L under both scenarios.		. Should be suitable for fish except for potential ice cover problems in localized shallow bays.

TABLE 3.16 (Cont'd)

Parameter/ Characteristics	Scenario 1	Scenario 2	Comments
Physical Characteristics			
. Turbidity			
Rafferty and Alameda	. Could have localized high turbidity near tributary mouths during runoff, especially on Rafferty. . Periodic incidents of high turbidity expected under high wind conditions, particularly for Rafferty.		. Apart from inflows, bank stability, water level fluctuations, and wind will be major factors for downstream conditions. . Deeper areas should have less turbidity.
. Colour			
Rafferty	. Wintertime colour developments expected - particularly in shallows regions. . Values in excess of 15 units could be periodically encountered.		. Winter and spring colour values should tend to be less than presently experienced. . Levels would not be expected to seriously affect users.
Alameda	. Lower colour generation expected than from Rafferty.		
. Temperature, °C			
Rafferty			. Dependent on mixing, ambient temperatures and depths. . Rafferty bottom temperatures of 2 - 3 °C less than surface may be expected. . Should be typical of Saskatchewan lakes. . Suitable for recreation.
summer (surface)	19 - 22	19 - 22	
winter	0 - 4	0 - 4	
Alameda			
summer (surface)	19 - 22	19 - 22	
(near bottom)	10 - 12	10 - 12	
winter	0 - 4	0 - 4	

TABLE 3.16 (Cont'd)

Parameter/ Characteristics	Scenario 1	Scenario 2	Comments
Heavy Metals/ Trace Substances			
. Heavy metals Rafferty and Alameda	. Generally expected to be low - near or below detection limits. . Some increases may occur for total forms during high turbidity events.		. Potential impact of leaching from flooded lands unknown. . Generally expected to have low values within objectives/ guidelines for identified uses.
. Iron, manganese Rafferty and Alameda	. May have increased concentrations near reservoir bottoms under ice cover or low oxygen/ anoxic conditions.		. Increases are expected to be periodic and should not affect uses.
. Boron, mg/L			
Rafferty			
max.	0.2	0.5	. Based on relationship with conductance.
average	0.02 - 0.1	0.02 - 0.1	. Should generally meet irrigation use criteria.
Alameda			
max.	L0.3	L0.3	. Based on Moose Mountain Creek data.
Mercury - Fish			
Rafferty and Alameda	. May exhibit short-term increases of mercury accumulations in fish tissue.		. Mercury values in soils unknown for Alameda. . Fish will require periodic monitoring to determine if problem develops.
Biocides			
Rafferty and Alameda	. May be periodic positive but low detections of 2,4-D, lindane, alpha-BHC		. Expected to be typical occurrences experienced in other Sask. waterbodies.

TABLE 3.16 (Cont'd)

Parameter/ Characteristics	Scenario 1	Scenario 2	Comments
Bacteriology			
Rafferty	. Except for potentially high coliform counts in the vicinity of the Weyburn effluent discharge during the April/October discharge periods, low populations of less than 1000 total coliforms/100 mL from human sources are expected.		. Other potential unquantifiable sources include livestock and wildfowl. . Due to residence times and volumes, general compliance for contact recreation and irrigation uses should be achievable during those periods of use.
Alameda	. Total coliform counts of less than 1000/100 mL from human sources are expected.		. No sewage discharges of immediate concern were identified. . See comments for Rafferty.
Aquatic Biology			
. Chlorophyll$_a$ (mg/m^3)			
Rafferty - average	19 - 13	56 - 31	. As a measure of algal densities, projections indicate eutrophic conditions in both reservoirs with the most severe growths (hypertrophic) occurring in Rafferty under Scenario 2 conditions.
- max.	37	100	
Alameda - average	14 - 10	17 - 11	
- max.	28	33	
. Phytoplankton (algae)			
Rafferty	. Favourable conditions exist for significant phytoplankton populations with normal cycling of diatoms, greens, and blue-greens predominance from spring through early fall. Initial operating years may be highly productive. Scenario 2 would be conducive to greater densities. Bloom forming blue-green growths could be anticipated in sheltered locales during hot, calm weather. Following reservoir stabilization, annual variations in grown densities may occur.		. Excessive nuisance algal growths - particularly of the blue-green species may periodically inhibit recreational uses during warm weather periods. . Collapse of algal blooms could cause temporary dissolved oxygen decreases to adversely affect fish. . Water supplies could experience taste and odour problems unless appropriate treatment is provided. . Growths, typical of south Sask. lakes, are expected over the long term.

TABLE 3.16 (Cont'd)

Parameter/ Characteristics	Scenario 1	Scenario 2	Comments
Alameda	. Similar to Rafferty except densities and possibly frequency of blue-green bloom formations are expected to be less.		
. Benthic Organisms Rafferty and Alameda	. Normal typical benthic populations are expected. Shallow areas with organic sediments will favour pollution tolerant organisms.		. Benthos will not directly affect users. Will provide food source for bottom scavenging fish.
. Macrophytes (aquatic weeds)			
Rafferty and Alameda	. Shallow water depth zones near the upper reaches or bays will favour growth of emergent vegetation such as cattails, bullrush, etc. Fluctuating levels, particularly in Rafferty, may promote emergent growth movement. In steep shoreline areas, substantial submergent growths are not expected. Beds of rooted submergent vegetation can be anticipated for mid-channel deeper portions of the reservoirs.		. Typical macrophyte growths are expected, which could be favourable to certain wildlife and aquatic fauna. . Depending on locations, recreational use and direct irrigation withdrawal could be impeded during maximum summer growth phases.

TABLE 3.17

SOURIS RIVER DOWNSTREAM REACHES

SUMMARY WATER QUALITY COMMENTS

Parameter/ Characteristic	Projections/Use Comments
Dissolved Salts	
. Conductance/ Total Dissolved Solids	. During reservoir release periods, spring through fall, conductance/TDS values will reflect reservoir quality. Lower reach below Moose Mountain Creek will have lesser concentrations. Average TDS values should be 600 mg/L or less. . Improvement expected over existing quality during summer-fall periods. Winter conditions will be essentially unaltered. . Quality should be compatible with all uses.
. Sodium Adsorption Ratio	. SAR may range up to 3.6 (Scenario 2) in reach to Moose Mountain Creek but generally should be well below 3. In the lower reach, values of 2 or less would generally be expected. . During the summer-fall periods, improvements would be realized over existing levels. . Projected levels should be satisfactory for unrestricted irrigation.
Nutrients	
. Nitrogen	. Total kjeldahl nitrogen could be increased to high levels of 3 - 4 mg/L in the first reach compared to 1 - 2 mg/L typically observed. Reductions below Moose Mountain Creek should occur with Alameda inflow. . Any Estevan effluent will marginally increase concentrations during discharge periods. . Surface water quality objectives (Sask) will continue to be exceeded. . Un-ionized ammonia concentrations could peridically exceed 0.02 mg/L during summer periods. . Water quality will be good for irrigation, but some fish toxicity may arise. The effects on water use (boiler feedwater) at the Estevan Generating Station should be reviewed.
. Phosphorus	. Due to potential phosphorus retention in the reservoirs, concentrations may be somewhat less than presently observed during spring and summer.

TABLE 3.17 (Cont'd)

Parameter/ Characteristic	Projections/Use Comments
. Phosphorus (Cont'd)	. Any Estevan effluent will add to levels during discharge periods, but increase should be minor. The downstream reach should have lower concentrations but may approach or exceed the objective level of 0.05 mg/L. . Sufficient phosphorus will probably be available to support aquatic vegetation growth.
Dissolved Oxygen	
	. Increased summer and fall flows should improve dissolved oxygen regime. . Due to probable algal growths, diurnal fluctuations would be expected. . Levels near saturation should occur during open water seasons. Winter quality will have D.O. similar to present conditions.
Physical Characteristics	
. Turbidity	. Turbidity reductions are generally anticipated particularly during spring season. Other seasons should have similar turbidity to present conditions.
. Colour	. Colour may be reduced during spring through fall seasons due to reservoir capture and increased summer-fall flows.
. Temperature	. During the summer, the low level reservoir releases may discharge cooler water, but it is expected temperatures will quickly rise to those of normal summer water and no substantive change over present experiences is forecast.
Heavy Metals/ Trace Substances	
. Heavy Metals	. Due to upstream sedimentation, heavy metals are expected to be generally low - near or below detection limits.
. Boron	. Boron should generally be below 0.5 mg/L during spring through fall periods and thus satisfactory for irrigation. . Some improvement over present conditions is expected.

TABLE 3.17 (Cont'd)

Parameter/ Characteristic	Projections/Use Comments
Biocides	. Biocides are expected to be virtually non-existent except for trace levels of 2,4-D, lindane, and alpha-BHC. . Downstream land use and agricultural practices may provide potential biocide sources.
Bacteriology	. Reach immediately below Estevan may experience high coliform counts during any effluent release periods or summer storm events. . Generally quality is expected to be suitable for all uses.
Aquatic Biology	
. Phytoplankton (algae)	. Sufficient nutrients should be available for algal growths, but increased flows should minimize ponding. . Under flowing conditions, diatoms and green algae may predominate.
. Macrophytes (aquatic plants)	. Changes in the flow regime may provide a more favourable habitat for aquatic plant growth. . Growths are not expected to be severe and should not interfere with potential uses.

4. MITIGATION CONSIDERATIONS

Major water quality impacts to the Souris River system will be dictated by the alterations in the nature of the watercourses and changes in the hydrological characteristics. Essentially, the water quality of the reservoirs will depend on the water inflows and outflows, while downstream, the water quality will reflect that at the reservoir discharge points and will be affected by release rates and durations. Due to the nature and magnitude of the projects, substantial mitigative options are not readily available.

As noted in the previous section, both positive and negative impacts could accrue from construction of the projects. Major water quality factors include dissolved salt levels, availability of nutrients such as nitrogen and phosphorus and the resultant effects on the aquatic productivity, dissolved oxygen regimes (particularly under ice cover) and possibly mercury accumulations in fish. This latter potential is essentially non-mitigative, but appropriate surveillance will be undertaken to monitor trends and identify any problems. Some features and developments associated with the projects will incorporate water quality protection measures. In addition, it is recognized that appropriate water quality surveillance and assessment will be a key not only to determine the maintenance of suitable water quality but also to enable the detection of any undesirable trends so that potential remedial action can be addressed. The following briefly discusses some mitigation considerations and activities that will have a bearing on water quality management.

4.1 Pollutant Source Control

Other sections of the environmental impact statement describe measures or developments that will be undertaken, some of which will have positive implications for water quality and protection of uses. Included are such items as fencing to prohibit direct access to Rafferty Reservoir from livestock associated with community pastures, the establishment of wetlands environment near the mouth of Roughbark Creek, management of wastes from cottage areas and related developments, and measures associated with the abandonment, flood-proofing, spill control and containment, etc., for oil field production, transmission, and disposal facilities. It is expected that the oil spill co-ops for the area will also review their contingency plans to recognize the change in environment and any spill containment measures which may have to be implemented.

The creation of wetlands environment and the associated civil structures in the upper portion of Rafferty Reservoir near #705 Grid Road could have a beneficial effect due to sedimentation and uptake of nutrients and other constituents by emergent vegetation. It is recognized that without harvesting, the net system balance of nutrients may not be substantially reduced, but it is expected that some modification with forms and surge suppression would occur. The creation of weirs and discharge structures could allow some aeration opportunity, and these will be designed to enhance any water quality improvement capability.

The only major point source for pollutants to either reservoir is from the City of Weyburn's treated sewage effluent. Presently data are lacking to fully characterize the performance of the new treatment facility and receiving stream impacts. Removal of the effluent was assessed for nutrient impacts under both hydrological regime scenarios. Under Scenario 2 (1955 - 1974) hydrological conditions, reductions in average total phosphorus and total kjeldahl nitrogen concentrations were found to be approximately 24% and 31% respectively. However, while this reduction in input would tend to lower average concentrations under the particular scenario and would minimize the peak concentrations within the period, the resultant values are still high and maintain the waters in a eutrophic category. For Scenario 1, marginal mean reductions of 12% phosphorus and 17% nitrogen were realized. Pending monitoring results and an assessment of the effect of the effluent on the main reservoir including potential reductions through the proposed wetlands area, this mitigation item may be worthy for consideration in the future, especially if Weyburn can entertain effluent disposal by land application.

Other potential waste inputs such as may arise from cottage developments or other activities will be subject to current provincial legislation which presently prohibits discharge of effluents into reservoirs.

The other major pollutant source in the system relates to the City of Estevan treated sewage effluent. There is potential that this effluent could be recycled for use at the Shand power station. This action will reduce the loading normally experienced into the Souris. Since the effects of Estevan are not of known major significance throughout the downstream reach, the impact of this removal cannot be accurately assessed at this time. It is expected that spring discharges would be magnified with less dilution while fall releases would be of a lesser impact due to increased river flows. However, reuse elsewhere would reduce the loading of some constituents, notably organic materials and nitrogen and phosphorus, and minimize potential concerns over bacteriological problems.

4.2 Design/Construction Activities

During construction of earthfill structures and from clearing and grubbing, etc., there will be disturbance to the aquatic environment. This may be manifested in increased short-term turbidity and other related suspended materials. The Authority will take necessary measures to minimize any adverse effects to receiving waters during the construction phase.

In conjunction with the final design of the reservoirs and downstream works, the Authority will carefully consider any water quality effects and potential measures that may be feasible within the constraints of the improvements to enhance water quality conditions within the reservoirs and in the downstream reaches.

With the potential establishment of bathing beaches on the reservoirs, contouring and any necessary importation of sand will be carried out. The Authority recognizes that the provision of properly contoured and sanded beaches will minimize growth of aquatic weeds and the production of turbidity within the swimming areas. Other reservoir construction design features that will be examined will include the feasibility of selected stripping and removal of organic materials to minimize potential dissolved oxygen problems and to thus create safety areas for fish. Pending water quality observations, the Authority is prepared to undertake an examination of other potential remedial measures such as artificial aeration but this would have to be assessed based on the particular circumstances and problems.

4.3 Operations

Although the operation of the reservoirs will largely be dictated to meet hydraulic considerations for apportionment and irrigation, operation strategies will include careful consideration of water quality aspects. Opportunity probably exists for improvements in downstream water, if necessary, by short-term reservoir releases. Some potential exists for control of dissolved salt levels through either Boundary Reservoir diversions or releases from the reservoir. However, the effects of this would have to be carefully considered in light of water supply forecasts and demands. It is expected that this capability will be rather limited.

Diversion of excess waters from Boundary upstream of the cooling water return canals will be of benefit for Rafferty. The impact on longitudinal effects for Boundary are unclear. Therefore, ongoing monitoring will be required to assess any detrimental effects on the lower reach of Boundary. Potential remedial action would include transfer to Boundary from Rafferty or a release at Boundary dam.

4.4 Monitoring and Surveillance

In consultation with Saskatchewan Environment, the Authority will undertake appropriate water quality surveillance and assessment. This surveillance will take the form of routine monitoring at key sites to establish a seasonal, primary data base, determine potential trends, and to assist with water management planning. Coupled with this will be special surveys and studies to periodically determine a broader quality spectrum and spatial or temporal effects.

To improve the data base and assist future water quality assessments and management activities, soil samples from selected, representative sites to be inundated at both reservoirs will be obtained prior to any flooding. Analyses will be obtained for surrogate salts, nitrogen, phosphorus, boron, mercury, and other parameters of interest.

While specific surveillance programs following commencement of construction have yet to be finalized, contemplated activities include:

a) Routine Monitoring (quarterly) -

i) Rafferty Reservoir - No. 705 grid
- No. 606 grid
- Near dam

ii) Alameda Reservoir - Upstream portion
- Near dam

iii) Souris River - No. 18 highway
- No. 9 highway
- Glen Ewen

iv) Moose Mountain Creek - No. 18 highway

Quality determinations would include general field analyses (temp, D.O., pH, etc.) plus laboratory analyses for major ions, nitrogen and phosphorus species, organic carbon, suspended solids, colour and turbidity.

It is assumed the data from SPC surveillance of Boundary Reservoir and from Weyburn/Estevan effluent and receiving water monitoring would be available.

b) Special Surveys

i) Reservoirs
- Depth profiles (D.O., temperature) - winter and summer.
- Longitudinal variations summer and winter.
- sediments, benthos.
- plankton (spring, summer, fall).
- fish (mercury)
- macrophyte surveys.

ii) Downstream Reaches (to reflect operating scenarios and uses)
- Spatial and temporal changes with releases.
- Diurnal effects.

The surveillance program incorporates existing major downstream water quality stations to maintain continuity of data and to assess the effects of the projects. Generally water quality surveillance activities would be undertaken at a reasonably intensive level during the initial years of filling and operations. Following experience and definition of potential trends, the programs would be moderated to ensure they are cost-effective and provide the necessary information to assist water management programs and to address the needs for potential users.

5. OVERALL ASSESSMENT

Due to the water quality monitoring activities of Saskatchewan Environment and Environment Canada, a reasonable water quality data base generally exists for the key sites on the main stem of the Souris River from below Nickle Lake to the international border and for the primary tributaries, Long Creek and Moose Mountain Creek, which are of importance to this assessment. These data enable a generally satisfactory appreciation of the physical and chemical characteristics of the waters under seasonal (and corresponding flows) conditions. In addition to the routine monitoring, the Souris River Basin Study (1978) provided data for intermediate stations and was a major source of aquatic biological information for the main stem Souris and Moose Mountain Creek sites. Unfortunately, data gathered during the Souris Basin Study must be tempered due to the extreme runoff events that preceded and occurred during the undertaking of that program. With the use of Boundary Reservoir by the SPC generating station and by the City of Estevan for water supply, additional studies are available for this Long Creek reservoir.

Uses for the Souris River do not include major consumers, but encompass a variety of small users such as irrigators, limited municipal water supply, stock watering, industrial cooling, and fish and wildlife that exist in the basin. Similarly major potential pollutant sources are rather limited. Sources include the City of Weyburn, which has recently substantially upgraded its sewage treatment facility, City of Estevan (treated sewage effluent and storm runoff), and minor thermal cooling (Estevan generating station). Other potential inputs include agricultural drainage, stock and wildlife activities, groundwater inflows, and wetlands overflows.

Based on the available data, it is apparent that water quality in the Souris River is largely governed by seasonal and related flow regime considerations. In a fashion typical of many prairie streams, spring and summer yields the most favourable quality for uses due to the increased flows, while during the late fall and wintertime, quality often deteriorates due to low flows, pooling, and ice cover concentration effects. Major dissolved salts ranged from reasonably low levels during spring with the snowmelt to considerably higher concentrations during late summer through to the winter period. Dissolved oxygen has been variable throughout the Souris River and demonstrates seasonal and diurnal fluctuations. Periodic summertime and more frequent wintertime depletions and low levels have been recorded. Turbidity and colour tend to be rather high, particularly in the upper reaches of the system and during the higher runoff events. Heavy metals, trace substances, and biocides have generally been at low levels, although some positive detections of heavy metals and biocides have occurred. Of the trace substances, boron and fluoride have periodically been high. The waters in the basin are subject to significant nutrient inputs and sufficient levels of phosphorus and nitrogen have been recorded that are favourable for the growth and maintenance of aquatic vegetation. Reservoirs in the system have been subject to normal cycling of algae types and periodic blooms of blue-green algae have occurred. The upper reaches are more conducive to the growth of emergent and submergent aquatic vegetation, while the lower reach appears to have a less suitable habitat for this type of growth.

Compared with Saskatchewan and Canadian water quality objectives and guidelines, the Souris River waters are in general compliance with many of the identified parameters but often exceed recommended maximum levels for nitrogen, phosphorus, and some of the dissolved salts. Additionally, dissolved oxygen levels periodically fall below recommended minimum levels. On balance Souris River quality is similar to that experienced in many other prairie streams.

Construction and operation of the major reservoirs, Rafferty on the Souris River and Alameda on Moose Mountain Creek, will create substantial changes to the regimes of these waterbodies. In addition, the change in river flow patterns could potentially affect water quality downstream of the reservoirs. Assessment of the water quality that may be realized these reservoirs was undertaken utilizing a water quality modelling technique for those characteristics that could be appropriately reviewed on this basis. For other parameters, more subjective comments based on experiences observed elsewhere and technical judgement were provided. The modelling and observations are not intended to provide finite or detailed examinations of various impacts but rather provide a more macro overview indicating potential average conditions. Extremes that may occur cannot be accurately projected based on the available data.

Primary reservoir water quality characteristics of interest include levels of dissolved salts, nutrient concentrations, dissolved oxygen, and potential resulting aquatic biological characteristics. Projections were made on the basis of two long-term hydrological regimes for the reservoir operations. These are considered to be typical and poor cases. The poor case may not represent the worst potential situation. For example, a less favourable regime could develop if events similar to the 1930s drought recurred. Nevertheless, it was felt that the two situations represented a reasonable range in potential variations. The hydrological events that accompany the initial years of operation of the reservoirs will have a significant influence on the resulting water quality within the reservoirs. Based on the modelling activities, this will be more critical for Rafferty Reservoir than for Alameda. Variations in the hydrology will affect dissolved salt levels, phosphorus and nitrogen concentrations, dissolved oxygen problem potentials, and the potential nuisance growths of algae. With lower inflow situations, higher TDS levels and nutrient concentrations are anticipated. The associated lower water levels will be conducive to greater oxygen depletions, particularly under ice cover conditions and could provide a more productive environment for aquatic plant growth.

Dissolved salts concentrations, although expected to fluctuate, are projected to be within levels satisfactory for most uses. Diversion of excess Boundary Reservoir flows to Rafferty Reservoir will provide some benefit to Rafferty. At the same time, the water quality in Boundary Reservoir will require ongoing monitoring to ensure that its quality for the generating station, City of Estevan water supply, and other current uses does not become adversely affected due to the lack of flushing at the lower end. If observations indicate this potential, then either transfer of water from Rafferty Reservoir or releases at Boundary Dam may be necessary to minimize any problems.

The levels of phosphorus and nitrogen within Rafferty, and to a lesser extent in Alameda, will be quite adequate to provide a eutrophic status to the reservoirs and promote aquatic biological productivity. The presence of these nutrients is largely non-mitigative due to the inputs through natural agricultural runoff and inundated soils. Termination of effluent discharges at Weyburn could provide some minor improvements in terms of phosphorus control depending on the hydrological events. The provision of a wetlands environment in the upper reaches of Rafferty Reservoir could afford some cleansing opportunity of the waters prior to reservoir entry.

It is projected that both reservoirs will be subject to typical aquatic vegetation growths experienced in southern Saskatchewan reservoirs and lakes. The lower reach of Rafferty Reservoir may not be as susceptible to the growth of emergent and submergent vegetation that will probably occur in the upper, shallower portions. Algal blooms of blue-green variety are possible during hot summer months. It is anticipated that Rafferty Reservoir may be subject to more extensive and higher algal densities than Alameda. Potential mitigation is rather limited although care and selection of use areas and perhaps some local design features to minimize any nuisance conditions can be incorporated.

Dissolved oxygen depletion to undesired low levels in shallow areas under ice cover is quite possible. The options for relieving this condition are limited although selected site stripping or other remedial features will be investigated. The use of artificial aeration would be a remote possibility.

The reservoirs could be subject to mercury accumulation in fish flesh, a situation common to newly flooded reservoirs. Although the exact magnitude of this is unknown, it is speculated that without any major source inputs other than inundated soils, accumulated concentrations in fish tissue will decrease with time.

Water quality downstream of the reservoirs will be largely dictated by the quality in the reservoirs and the release patterns. It is expected that the Souris River will not have any major water quality concerns during the open water season and will provide a more uniform quality to that which has been presently observed. Wintertime quality is expected to be relatively unchanged.

With respect to the existing situation in the Souris River, the creation of two large reservoirs will substantially alter the water regime. Nevertheless, the water quality is not expected to materially deteriorate over that presently observed. In fact, improvements will be noted on a year-round basis due to the presence of deeper waters. Downstream open water quality over the entire spring through fall seasons is expected to improve. The reservoirs will provide some instream treatment such as sedimentation and retention of certain constituents and, as well, will tend to modify the concentrations of flow related characteristics such as total dissolved salts, turbidity, colour, etc. The downstream waters will be reasonably fertile and typical aquatic biological growths are expected. The City of Estevan through either urban stormwater discharges or through effluent discharges (if effluent is not used elsewhere) may have a more marked effect during springtime due to the reduction of dilution capability. Fall impacts could be lessened because of additional dilution. Opportunity could be available during operation of the reservoirs to improve water quality or alleviate site-specific quality problems with periodic releases. Alameda Reservoir is generally projected to have better quality than that in Rafferty Reservoir. Releases through Moose Mountain Creek will improve water quality downstream to the border. A simplified impact summary, comparing existing and projected water quality for selected parameters or groups is presented in Table 5.1. Based on the available information and projections, known water uses should not, in general, be inhibited.

TABLE 5.1

SIMPLIFIED COMPARATIVE IMPACTS SUMMARY
EXISTING VS PROJECTED WATER QUALITY

Water Quality Parameter/ Characteristic	Reach and Season Souris R above Long Cr (Rafferty Res)			Souris R Long Cr to Moose Mtn Cr			Lower Moose Mtn Cr (Alameda Res)			Souris River Moose Mtn Cr to Border		
	Sp	S-F	W	Sp	S-F	W	Sp	S-F	W	Sp	S-F	W
Dissolved Salts (TDS, Cond.)	-	0	+	-	+	0	+	+	+	+	+	0
Total Nitrogen	-	-	+	-	-	0	-	-	+	+	+	0
Total Phosphorus	+	+	+	+	+	0	+	+	+	+	+	0
Dissolved Oxygen	0	0	-	0	+	0	0	0	+	0	+	0
Turbidity	+	-	0	+	+	0	+	0	+	0	0	0
Colour	+	0		+	+	0	+	+	+	+	+	0
Heavy Metals, Trace Substances, Biocides	0	0	+	0	+	0	0	0	0	0	0	0
Algae	0	-	-	0	+	0	0	-	-	0	-	0
Emergent, Submergent plants		+			-			+			-	

Notes:
- Comparisons based on available median data and average projections.
- Impact symbols: - = increased levels, populations or inferior conditions, 0 = insignificant change, + = decreased levels or improved conditions.

With the significant changes in the regime on the Souris River, ongoing water quality monitoring and assessment will be required and undertaken. Coupled with monitoring, design features, operations, and developments will be examined to assess water quality implications and to provide an opportunity for enhancement, if possible. Following establishment of the reservoirs, both routine and special survey monitoring will be undertaken to maintain up-to-date characterizations so that any potential problems can be examined and mitigation planned, and to provide guidelines to ensure appropriate water quality management in terms of overall water management programs for the system.

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APPENDIX

GLOSSARY

Adsorption	The attachment of substances to the surface of another.
Aeration	The process of adding air to a substance such as water.
Aerobic	The presence of dissolved oxygen or the requirement for oxygen for something to exist or proceed.
Aesthetic	A sensory perception (appearance, odour, etc.).
Algae	A large group of aquatic plants which are mainly microscopic.
Anaerobic	Absence of dissolved oxygen or the requirement for no dissolved oxygen for something to exist or proceed.
Bacteriology	The science that deals with bacteria.
Benthos	Organisms that live in or on the bottom subsurface of waterbodies, usually invertebrates.
Bio-accumulation	Process where substances are taken up either directly or indirectly, and retained by living organisms.
Biocide	A substance such as herbicides, insecticides, etc., which destroys living organisms.
Bio-degradation	Process where substances are broken down into other substances by living organisms.
Biochemical Oxygen Demand (BOD)	A measure of decomposable organic material.
Biomass	The weight of living organisms within a certain area.
Biota	All living plant and animal organisms.
Bloom	Rapid growth of a particular organism or group of organisms for a short period of time; may develop into visible mats.
Cation	A positively charged ion.
Chlorophyll	Green pigmented material in plants used in photosynthesis.
Coliforms	Bacteria which inhabit the large intestine of many vertebrates; used as an indicator for bacterial contamination in water.

Colloid	A substance made up of very small particles which do not settle out of solution or suspension by the force of gravity.
Colour (apparent)	The colour of water due to colloidal or suspended matter.
Conductance	The readiness of a substance to transmit an electrical current; used as a measure of dissolved salts or salinity. Also known as conductivity.
Detection Limit	The lowest concentration of a substance which can be determined by present analytical procedures.
Detritus	Organic matter resulting from the process of decomposition.
Dissolved Constituent	Substances in water which are not retained by a 0.45 um membrane filter.
Dissolved Oxygen	The concentration of oxygen present in a liquid medium, usually water.
Dissolved Salts	The concentration of major ions dissolved in a liquid medium, usually water.
Diurnal	A daily cycle (includes day and night).
Diversity Index	A numerical ratio of the number of different species within a community in relation to values assigned to such factors as numbers of organisms, biomass, productivity, etc.
Effluent	Material discharged from a facility into the environment (e.g. treated sewage).
Epilithic	Living on an inorganic surface (i.e. rocks).
Epiphytic	Living on the surface of plants.
Eutrophic	Referring to a waterbody rich in dissolved nutrients and highly productive, usually supporting substantial aquatic vegetation growths.
Epilimnion	The portion of a waterbody above the thermocline which typically consists of warmer, lighter, oxygen-rich water.
Eutrophication	The aging process of a waterbody often associated with increased productivity.

Evapotranspiration	Evaporation of water from plants and the surrounding soil or water.
Guideline	Limit of concentration, usually numerical, of a particular constituent which is recommended for the maintenance of a certain quality or use.
Hardness	A measure of calcium and magnesium in water.
Heavy Metals	A group of substances known by their metallic properties, such as copper, iron, silver, zinc.
Humic Substances	Organic substances derived from the partial decomposition of plant and/or animal matter; in water, they are usually colloids.
Hypolimnion	The portion of a waterbody below the thermocline which is usually of consistent temperature and not influenced by surface conditions except during times of turnover; it typically consists of colder heavier water.
Invertebrates	Organisms which do not have a dorsal spinal column.
Ion	An atom or group of atoms which possesses a positive or negative electrical charge resulting from the loss or gain of an electron.
Ionic Species	Types of ions.
Leaching	Process of passing liquid through a substance resulting in the dissolving out of soluble constituents.
Limnology	The study of the physical, chemical, and biological aspects of fresh waterbodies.
Littoral	Pertaining to or situated on or near the shore.
Macrophyte	A macroscopic plant.
Macroscopic	Large enough to be seen with the naked eye.
Median	A numerical value in a series of values above and below which there are an equal number of values or which is the arithmetic mean of the two middle values if a middle number does not exist.
Mesotrophic	Moderate in dissolved nutrients and of medium productivity.

Methylation	To bring into contact with the methyl (CH$_3$) group of substances.
Morphometry	The physical structure or characteristics of a body of water.
Not Detectable	Below the present detection limit of a particular analytical method.
Nutrients	Elements and/or compounds necessary for the maintenance, growth, and reproduction of living organisms.
Objective	Limit of concentration, usually numerical, of a particular constituent which has been set to protect the quality or use of a particular area.
Oligotrophic	Low in dissolved nutrients and low in productivity.
Organochlorine Compounds	Organic compounds, often synthetically produced or manufactured, that contain chlorine.
Organism	Any living thing.
Parameter	A measurable element or characteristic, the values of which determine the features of something.
Percentile	The value on a 1-100 scale which indicates the percent of a distribution of data that is equal to or below it.
Pesticide	A substance used to destroy unwanted organisms.
Photosynthesis	The production of chemical compounds including oxygen, using radiant energy in the process (i.e. chlorophyll-bearing plant tissues form carbohydrates in the presence of light).
Phytoplankton	Small, usually microscopic, floating plants (i.e. algae), which are considered the primary producers in an aquatic community.
Plankton	Small floating plant and animal life in a waterbody.
Primary Production	The rate at which producers (usually plants) utilize radiant energy via photo- and chemosynthetic processes in the production of organic substances which serve as food for consumers.

Radioactivity	The property of emitting alpha, beta, or gamma rays by certain elements via the disintegration of atomic nuclei (e.g. uranium).
Radionuclide	A substance capable of radioactive emissions.
Range	The difference between the least and greatest values in a group of data.
Raw Water	Untreated ground or surface water used as a source for drinking water.
Reduction	A process where a substance's chemical form is changed.
Sodium Adsorption Ratio(SAR)	A calculated numerical index of the relation of sodium content to calcium and magnesium content; it is a measure of the effect excess sodium has on soil structure, infiltration, permeability, and aeration.
Species	A level of biological classification made up of related organisms which are potentially capable of inter-breeding; the usual designation is a two-part name consisting of genus and species (e.g. *Homo sapiens*).
Supersaturation	Beyond the point of saturated capacity (with respect to water quality, this term normally refers to dissolved oxygen, where the concentration is greater than 100%).
Suspended Solids	Substances in a liquid medium, usually water, which can be filtered out.
Thermocline	A horizontal layer of water in a waterbody in which there is the greatest rate of decrease in temperature; this layer separates the upper epilimnion from the lower hypolimnion.
Total Dissolved Solids(TDS)	A measure of the primary dissolved salts in water.
Turbidity	A measure of the opaqueness or cloudiness of a substance.
Zooplankton	Small floating animals which are considered the primary consumers in an aquatic community.

LIST OF THE ELEMENTS AND SYMBOLS

	Symbol
Actinium	Ac
Aluminum	Al
Americium	Am
Antimony	Sb
Argon	Ar
Arsenic	As
Astatine	At
Barium	Ba
Berkelium	Bk
Beryllium	Be
Bismuth	Bi
Boron	B
Bromine	Br
Cadmium	Cd
Calcium	Ca
Californium	Cf
Carbon	C
Cerium	Ce
Cesium	Cs
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Curium	Cm
Dysprosium	Dy
Einsteinium	Es
Erbium	Er
Europium	Eu
Fermium	Fm
Fluorine	F
Francium	Fr
Gadolinium	Gd
Gallium	Ga
Germanium	Ge
Gold	Au
Hafnium	Hf
Hahnium	Ha
Helium	He
Holmium	Ho
Hydrogen	H
Indium	In
Iodine	I
Iridium	Ir
Iron	Fe
Krypton	Kr
Kurchatovium	Ku
Lanthanum	La
Lawrencium	Lr
Lead	Pb
Lithium	Li
Lutetium	Lu
Magnesium	Mg
Manganese	Mn

	Symbol
Mendelevium	Md
Mercury	Hg
Molybdenum	Mo
Neodymium	Nd
Neon	Ne
Neptunium	Np
Nickel	Ni
Niobium	Nb
Nitrogen	N
Nobelium	No
Osmium	Os
Oxygen	O
Palladium	Pd
Phosphorus	P
Platinum	Pt
Plutonium	Pu
Polonium	Po
Potassium	K
Praseodymium	Pr
Promethium	Pm
Protactinium	Pa
Radium	Ra
Radon	Rn
Rhenium	Re
Rhodium	Rh
Rubidium	Rb
Ruthenium	Ru
Samarium	Sm
Scandium	Sc
Selenium	Se
Silicon	Si
Silver	Ag
Sodium	Na
Strontium	Sr
Sulfur	S
Tantalum	Ta
Technetium	Tc
Tellurium	Te
Terbium	Tb
Thallium	Tl
Thorium	Th
Thulium	Tm
Tin	Sn
Titanium	Ti
Tungsten	W
Uranium	U
Vanadium	V
Xenon	Xe
Ytterbium	Yb
Yttrium	Y
Zinc	Zn
Zirconium	Zr

AQUATIC BIOLOGICAL CLASSIFICATIONS
SOURIS RIVER BASIN DATA

PHYLUM	CLASS	SUBCLASS	DIVISION	ORDER	SUBORDER/ FAMILY	EXAMPLE GENUS/SPECIES	COMMON NAME
PHYTOPLANKTON							
Cyanophyta	Myxophyceae					Anabaena sp. Aphanizomenon flos-aquae Microcystis aeruginosa	Blue-green algae
Chlorophyta	Chlorophyceae					Coelastrum microporum Oocystis sp. Pediastrum sp. Scenedesmus sp.	Green algae
Chrysophyta	Bacillariophyceae					Asterionella formosa Cyclotella sp. Navicula sp. Nitzschia sp.	Yellow-green algae Diatoms
	Chrysophyceae						
Euglenophyta						Euglena sp. Phacus sp. Trachelomonas sp.	Euglenoids (pigmented flagellates)
Pyrrhophyta	Cryptophyceae					Crytomonas sp. Rhodomonas sp.	Cryptomonad's
	Dinophyceae					Ceratium sp. Peridinium sp.	Dinoflagellats
MACROPHYTES							
Pteridophyta					Equisetaceae	Equisetum sp.	Horsetails
Spermatophyta	Angiospermae						Vascular plants Flowering seed plants
					Alismaceae	Sagittaria sp.	Water plantains
					Ceratophyllaceae	Ceratophyllum demersum	Hornworts
					Cyperaceae	Eleocharis sp.	Sedges
						Scirpus sp.	
					Gramineae	Spartina pectinata	Grasses
					Haloragidaceae	Hippurus vulgaris	Water milfoils
					Hydrocharitaceae	Elodea canadensis	Frogbits
					Juncaceae		Rushes
					Labiatae	Mentha arvensis	Mints
					Lemnaceae	Lemna minor	Duckweeds
					Lentibulariaceae	Utricularia minor	Bladderworts
					Najadaceae	Potamogeton sp.	Pondweeds
					Polygonaceae	Polygonum longistylum	Buckwheats
					Ranunculaceae	Ranunculus sp.	Buttercups
					Salicaceae	Salix sp.	Willows
					Typhaceae	Typha latifolia	Cattails
					Umbelliferae	Sium suave	Parsleys

PHYLUM	CLASS	SUBCLASS	DIVISION	ORDER	SUBORDER/ FAMILY	EXAMPLE GENUS/SPECIES	COMMON NAME
ZOOPLANKTON							
Protozoa							Protozoans
	Ciliata						Ciliates
	Mastigophora						Flagellates
Coelenterata							Hydroids
Rotifera						Brachionus sp. Keratella sp.	Rotifers
Nematoda							Roundworms
Annelida	Oligochaeta						Aquatic earthworms
Arthropoda	Arachnoidea			Hydracarina			Water mites
	Crustacea	Branchiopoda	Eubranchiopoda	Anostraca		Artemia salina	Fairy shrimps
				Conchostraca			Clam shrimps
				Notostraca			Tadpole shrimps
			Oligobranchiopoda	Cladocera		Daphnia sp. Bosmina sp.	water fleas
		Ostracoda		Podocopa			Seed shrimps
		Copepoda		Branchiura			Fish lice
				Eucopepoda	Calanoida		Copepods
					Cyclopoida	Cyclops sp.	
					Harpacticoida		
		Malacostraca	Peracarida	Isopoda			Aquatic sow bugs
				Amphipoda		Gammarus sp.	Scuds, side-swimmers
	Insecta			Diptera	Tendipedidae (Chironomidae)		midges
BENTHOS							
Annelida	Hirudinea						Leeches
	Oligochaeta						
	Polychaeta						
Arthropoda	Arachnoidea						
	Crustacea	- See Zooplankton. Malacostraca	Eucarida	Decapoda			Fresh water shrimp Crayfish
	Insecta			Coleoptera	Curculionidae Elmidae		Beetles weevils
				Diptera	Tipulidae		Crane flies
					Culicidae		Mosquitoes
					Tendipedidae		Midges
					Ceratopogonidae		Biting midges
					Tabanidae		Horseflies
					Rhagionidae		Snipe flies
				Ephemeroptera	Baetidae Ephemeridae Heptageniidae		Mayflies
				Hemiptera	Corixidae		True bugs
				Lepidoptera			Aquatic caterpillars
				Megaloptera			Alderflies, fish flies
				Neuroptera			Spongilla flies
				Odonata	Anisoptera		Dragonflies
					Zygoptera		Damselflies
				Plecoptera			Stoneflies
				Trichoptera	Hydropsychidae Leptoceridae Rhyacophilidae		Caddis flies
Mollusca	Gastropoda						Snails, limpets
	Pelecypoda				Sphaeriidae		Clams, mussels

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= CONDUCTIVITY

MEAN VALUE +– STD
NEAR GLEN EWEN

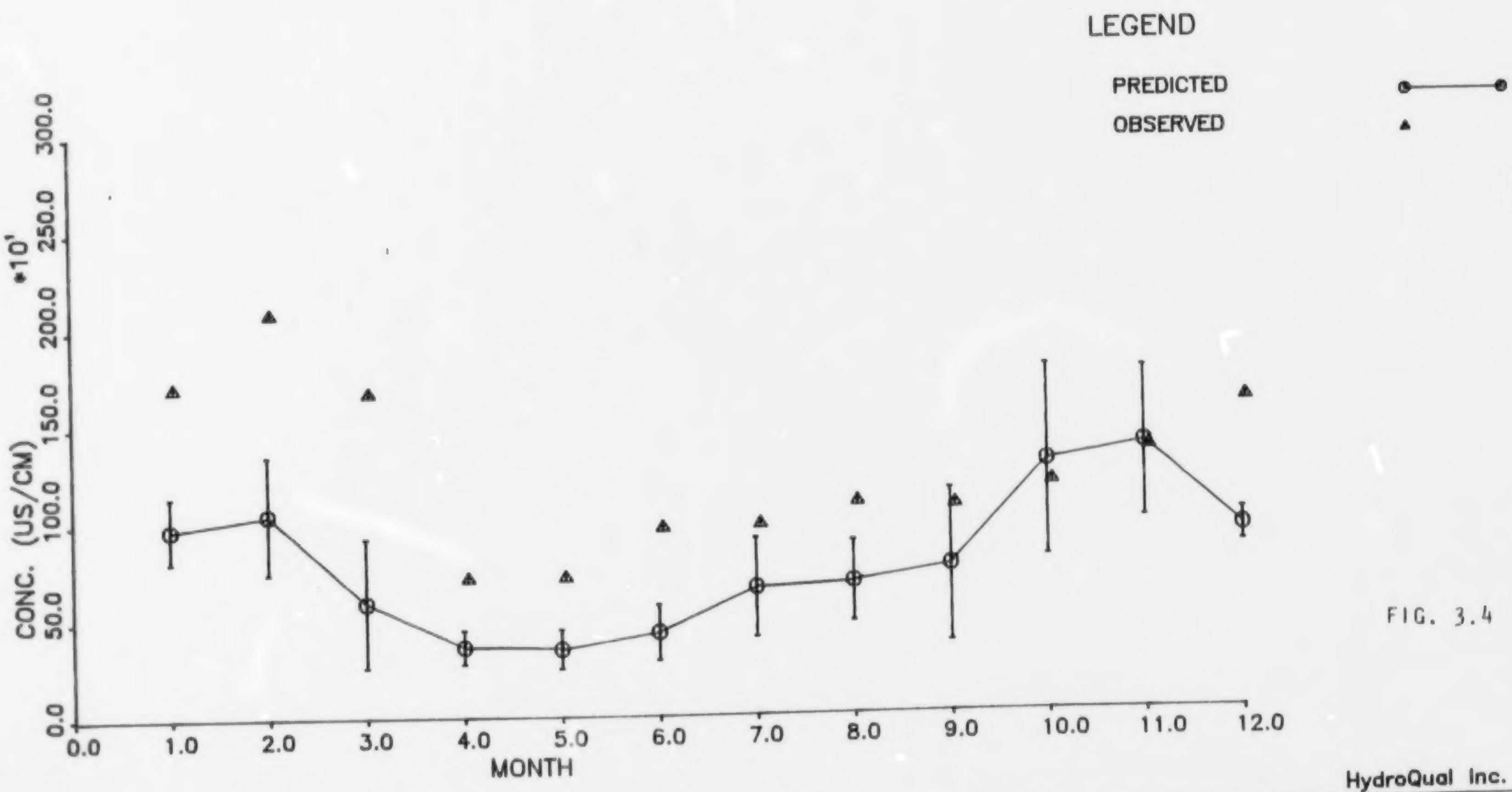


FIG. 3.4

HydroQual Inc.

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= SODIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

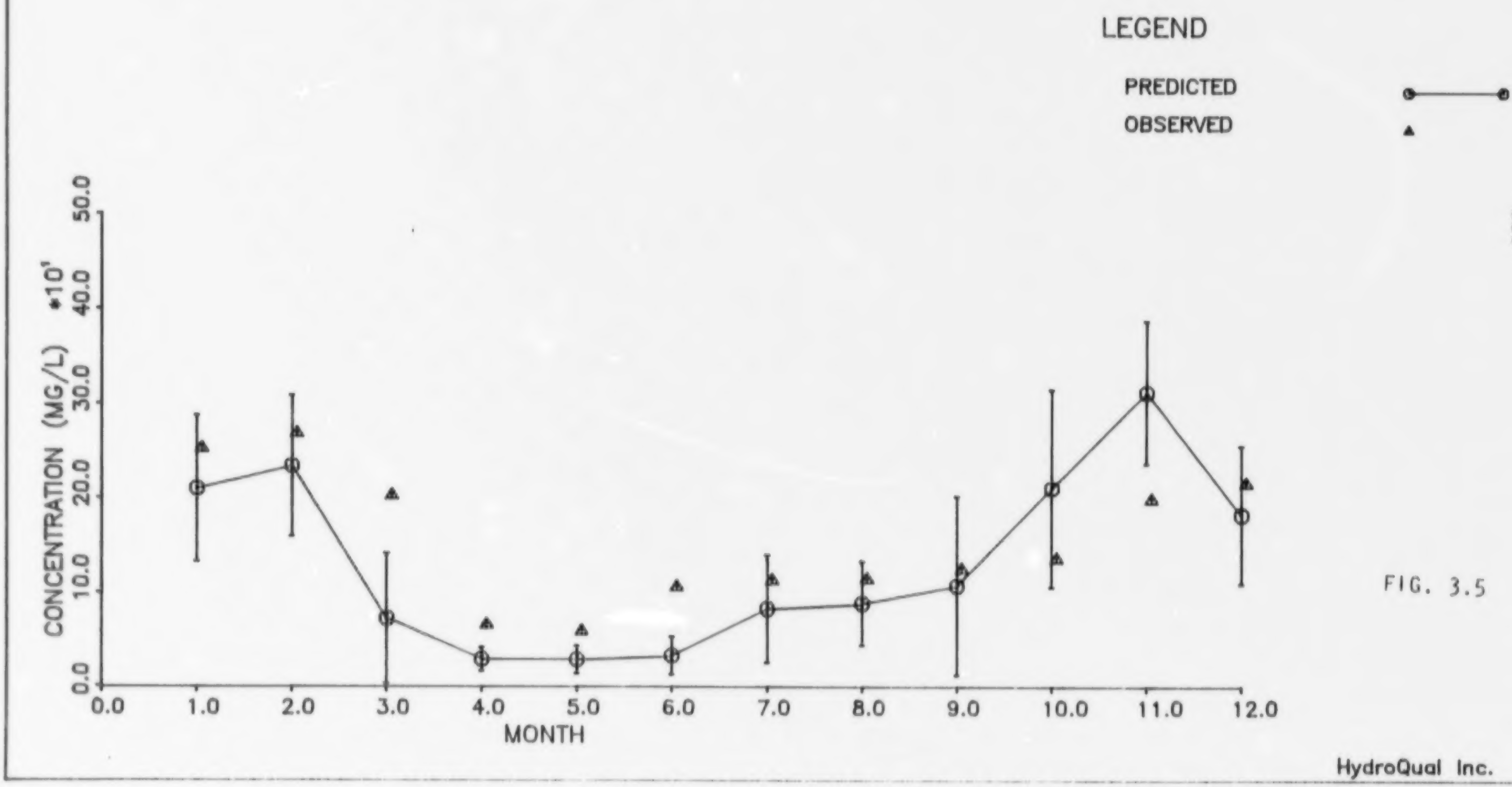


FIG. 3.5

HydroQual Inc.

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= CHLORIDE

MEAN VALUE +– STD
NEAR GLEN EWEN

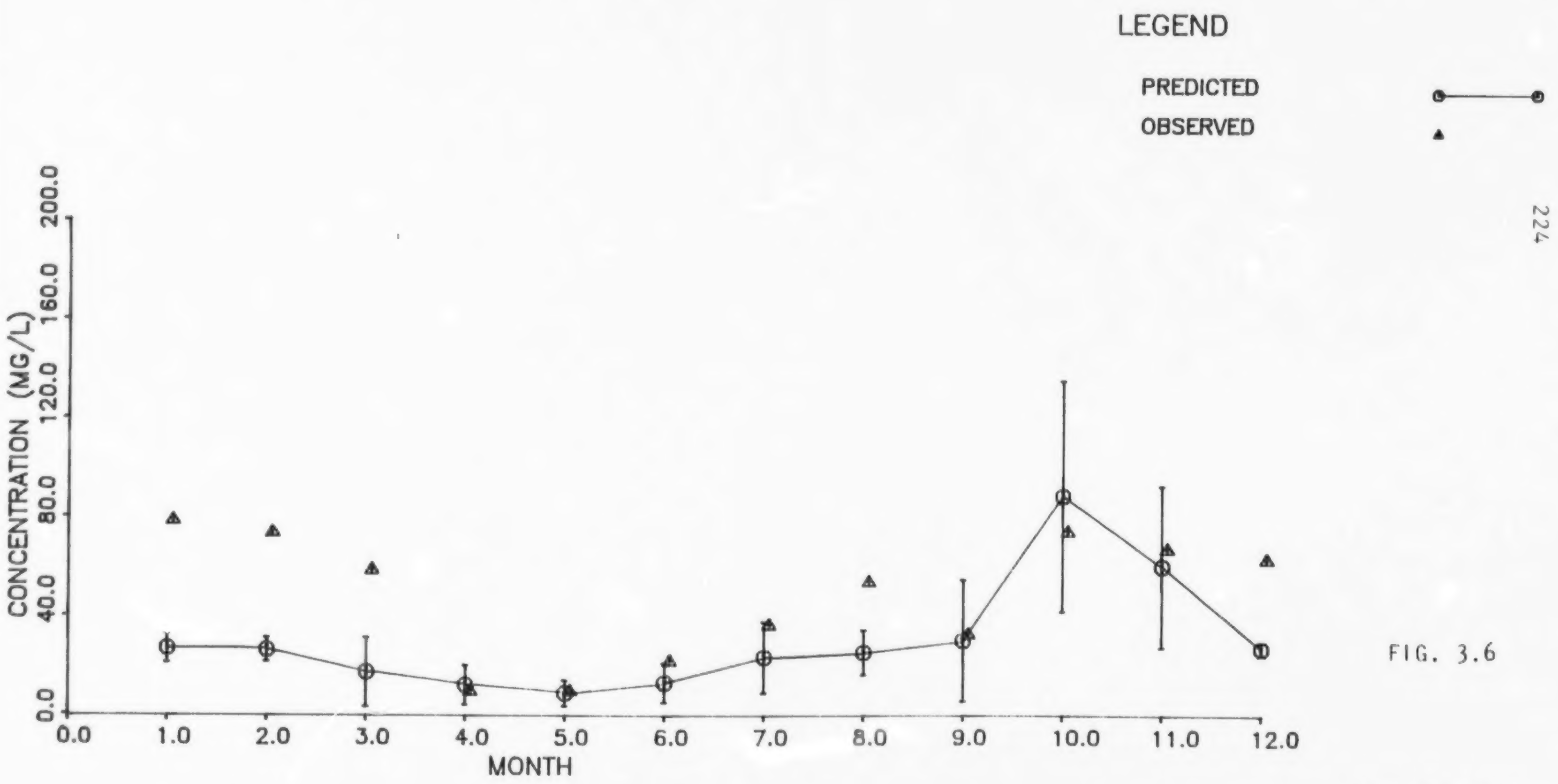


FIG. 3.6

HydroQual Inc.

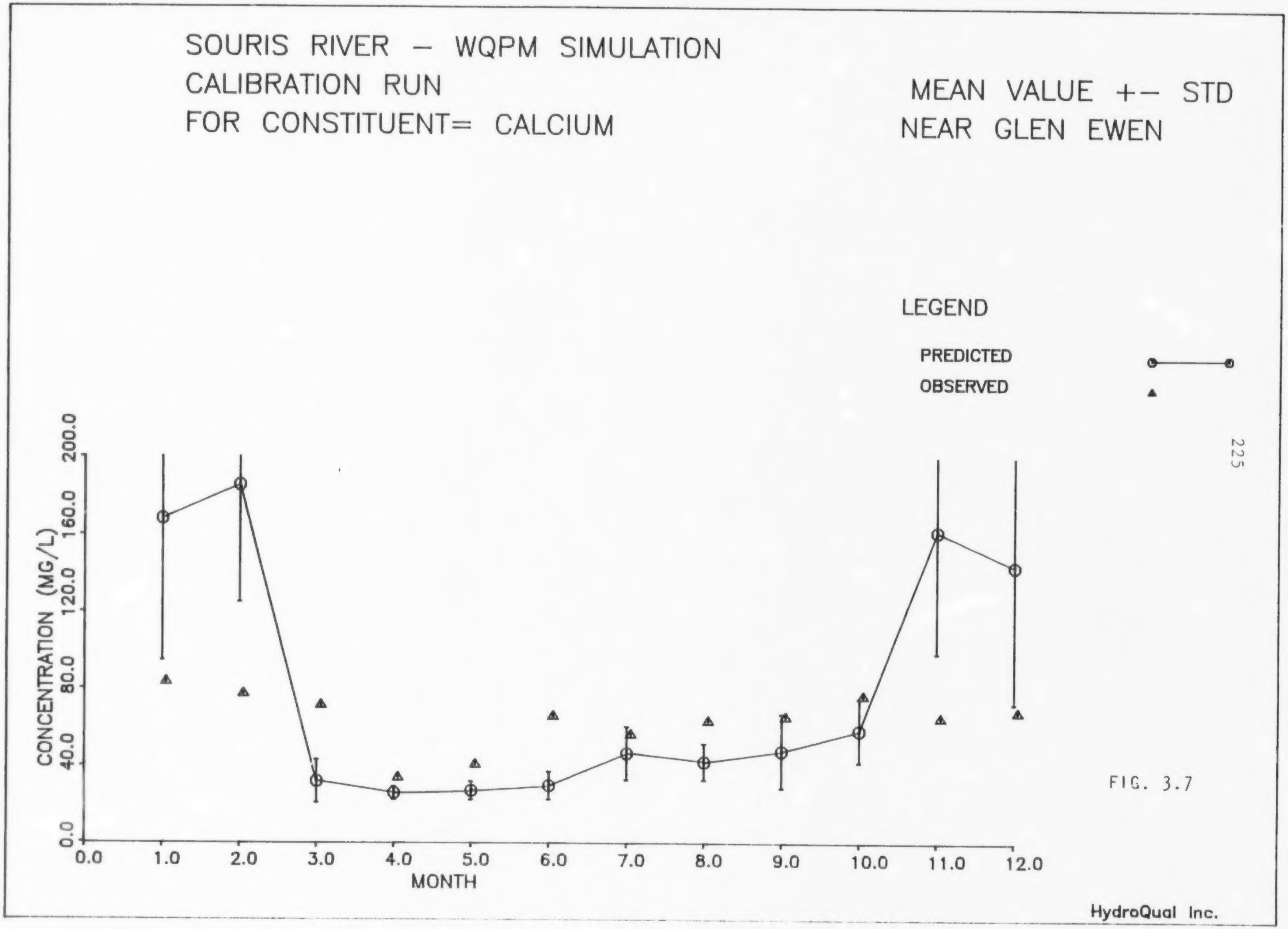
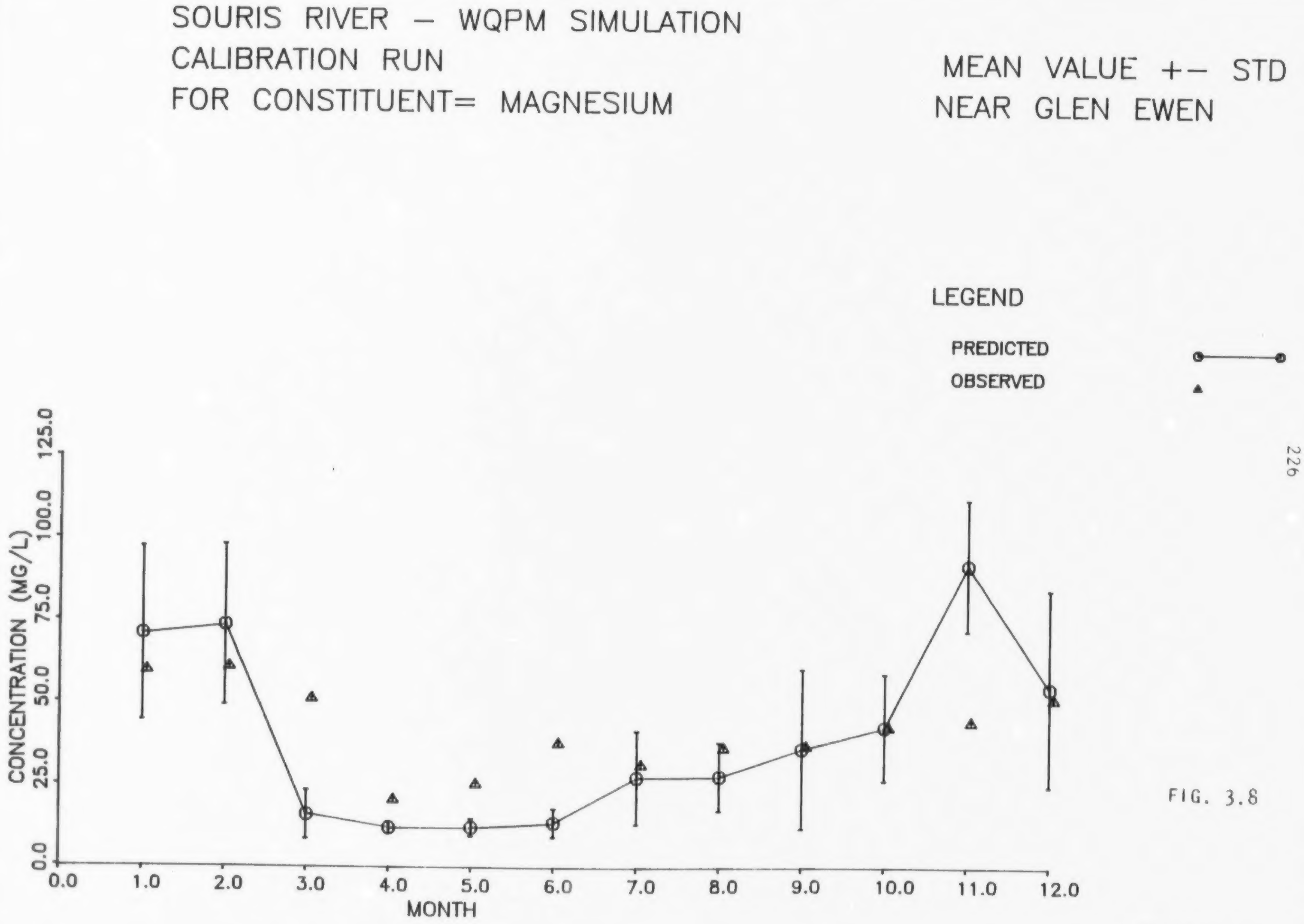

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= CALCIUM
MEAN VALUE +– STD
NEAR GLEN EWEN
LEGEND
PREDICTED
OBSERVED
CONCENTRATION (MG/L)
0.0
40.0
80.0
120.0
160.0
200.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
MONTH
HydroQual Inc.

FIG. 3.7



SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= MAGNESIUM

MEAN VALUE +– STD
NEAR GLEN EWEN

FIG. 3.8

HydroQual Inc.

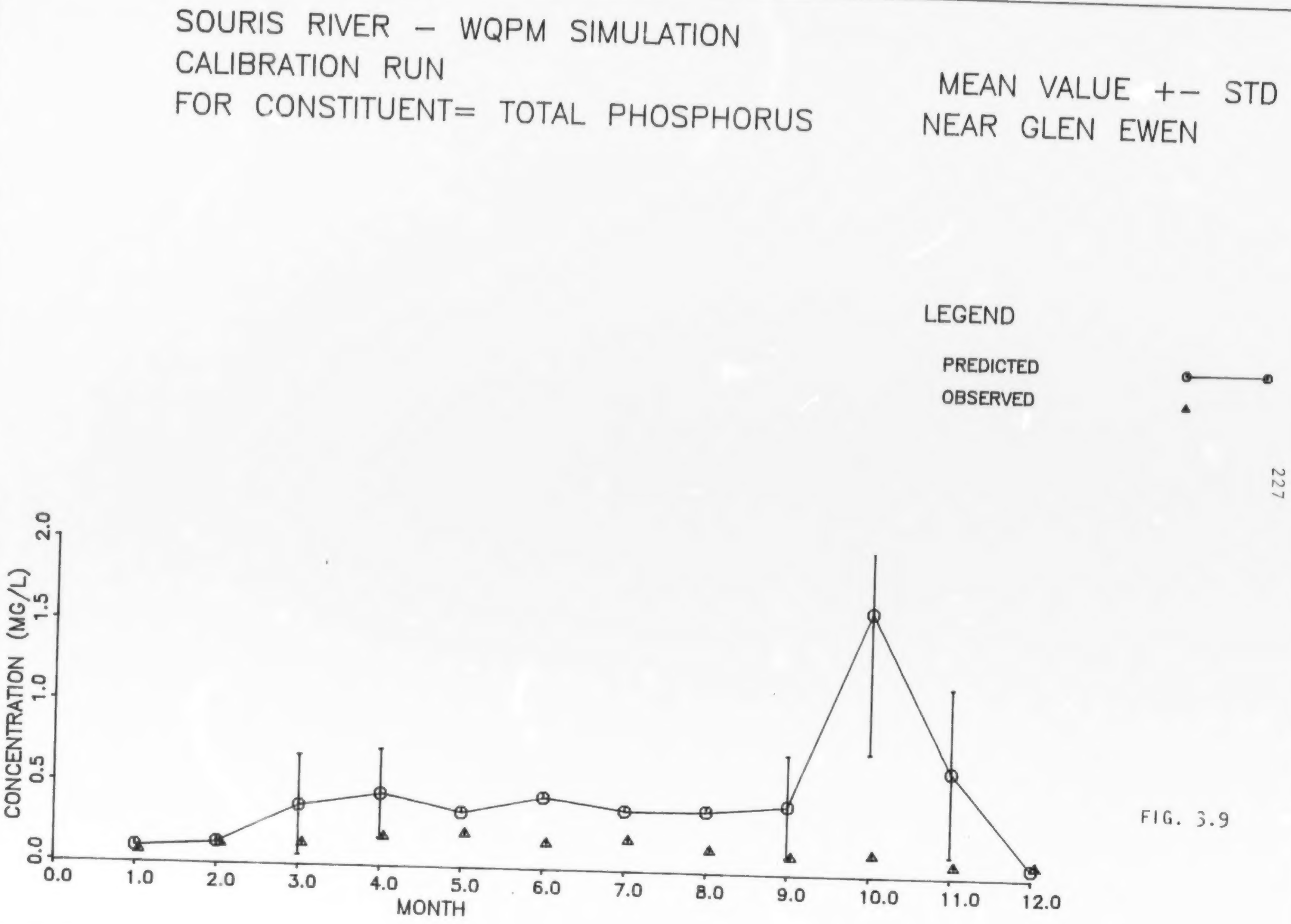

SOURIS RIVER – WQPM SIMULATION
CALIBRATION RUN
FOR CONSTITUENT= TOTAL PHOSPHORUS
MEAN VALUE +– STD
NEAR GLEN EWEN
LEGEND
PREDICTED
OBSERVED
CONCENTRATION (MG/L)
0.0
0.5
1.0
1.5
2.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
MONTH

FIG. 3.9